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JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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American Welding Society

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AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

Volume 6 DECEMBER, 1927 Number 12

SAMUEL WYLIE MILLER MEDAL

Through the generosity of S. W. Miller, a past president of the American Welding Society and Consulting Engineer of the Union Carbide & Carbon Company, there has been established by the society a gold medal to be known as the "Samuel Wylie Miller Medal." This medal is to be awarded annually during the lifetime of Mr. Miller for meritorious achievement in certain branches of the welding art—the award to be made under the conditions prescribed by a board of trustees.

Under the terms of the gift, the medal is to be administered by a self-perpetuating board of trustees consisting of E. H. Ewertz, C. A. McCune and F. M. Farmer, chairman. The sum of $150 is to be paid to the American Welding Society on or before the first day of January of each year for the support of the medal.

The following rules and regulations governing the award of the medal have been drawn up by the Board of Trustees:

1. The name of the medal shall be the "Samuel Wylie Miller Medal."
2. It shall be awarded annually for an outstanding development which has contributed conspicuously to the advancement of the art of gas fusion welding or electric arc fusion welding —such development to be described in a paper written in English which shall be submitted to the Board of Trustees on or before Dec. 31 preceding the year in which the award is to be made.
3. Individuals only, but of any country and of any age, shall be eligible for the award.
4. The Board of Trustees reserves the right to withhold making an award in any calendar year when in its judgment no development has been presented to it which merits the medal.
5. The award shall be announced and the medal together with a suitable certificate shall be presented at the annual meeting of the American Welding Society, at which time the paper on which the award is based shall be read by its author. The paper shall be subsequently published in the *Journal of the American Welding Society.*

Mr. Miller, the donor of the medal, has always been associated with gas arc welding and electric arc welding, and it seemed fitting to the board, therefore, that the award should be limited to these two branches of welding.

Any development in these two fields of welding which has contributed conspicuously to the advancement of the art will be eligible for the prize. Examples of such a development are an invention, development of a design which makes for pronounced progress in the application of welding in the structural steel field or any other metal fabricating field, important research work and

application of a standard welding process in a new and unique field.

A photograph of this medal is shown above. This is at present one of the highest honors which can be awarded to original workers in the welding field.

BOUND VOLUMES

At the request of a number of members of the Society we have been able to make arrangements whereby those members who so desire may have their JOURNALS bound for the twelve month period in permanent book form with an imitation leather binding. Those members desiring to avail themselves of this opportunity should send their JOURNALS for the year 1927 to Mr. H. Arthur Busch, Thomas Russell & Son, Crafts Building, Eighth Avenue and Thirty-third Street, New York City.

The charge for this binding will be $1.50, and a bill will be rendered from *Society Headquarters*.

In order to take advantage of this low figure it is necessary that these Journals should be sent to reach Mr. Busch not later than Jan. 31, 1928. Missing numbers of the JOURNAL may be obtained from *Society Headquarters* at 50c. per copy.

For the benefit of those who do not have complete sets of the JOURNAL, the Society binds a limited number of Journals in book form which may be obtained from the *Society Headquarters* at $5 per volume.

A PHYSICAL STUDY OF THE MOKELUMNE PIPE LINE

By Lloyd T. Jones and Walter S. Weeks. University of California Press. Berkeley. Cal.

I—Motion of Pipe Line.
II—Water-Pressure Stress.
III—Cold-Water Stress.
IV—Poisson Stress.
V—Welding Stress.
VI—Temperature Stress.
VII—Retaining Welds.
VIII—Closing Gaps by Expansion.
IX—Programs for Laying, Welding, Backfilling.

75 pages; 60 figures in text. Paper, postpaid, $1.

This study is the first comprehensive publication on pipe line stresses. The stresses are classified and carefully described. The relation of each stress to the construction and operation of the pipe line is fully set forth.

Experimental verification of the conclusions was obtained by exact measurement of the stresses and motions of the Mokelumne Pipe Line which is to carry water from the Sierra Nevada foothills to Berkeley, Cal. This 65-inch steel pipe line was the "laboratory" in which the analysis of stresses was verified.

The study relates particularly to the acetylene welded girth joint, but most of the stresses encountered are met in every pipe line regardless of method of joining.

The manuscript of Professor Jones' paper delivered before the New York Sections of the American Welding Society and the American Society of Mechanical Engineers was printed in the June, 1927, number of this JOURNAL. The bulletin just published is a much more detailed account.

The motion of the free end of the pipe line is shown to be definitely related to the metal temperatures. It is clearly brought out that there is a best and a worst time for laying for welding and even for backfilling the pipe.

Expansion joints are discussed and the reasons given for the authors' belief that expansion joints are unnecessary and undesirable in any underground water pipeline.

The statistical account of field breakage discloses the interesting fact that the per-joint footage of rivets removed exceeded the footage of weld removed.

Professors Jones and Weeks are to be commended for a noteworthy contribution to engineering and Mr. Davis and the Board of Directors of the East Bay Municipal Utility District for releasing the material for publication by the University of California.

MEMBERSHIP

Many times there have been emphasized at meetings and in the Journal, the importance of increasing the membership. Increased membership means increased support for the Society's work both by increasing its revenue and by adding additional supporters and active participants.

Getting new members is an obligation and duty that should not be dodged by the membership at large of the Society. The getting of one new member a year is just as important to the Society as payment of one's own dues. The importance of an active membership is emphasized in the November, 1927, issue of the American Society for Testing Materials Bulletin.

Two paragraphs on this subject are reproduced below.

> "No technical society can be stronger than its membership. A strong virile Society must have active members, active in advancing its work, in furthering its purposes, in increasing its usefulness through utilizing its services, and in bringing in new active members, who will make possible even greater accomplishments and who themselves will profit through membership in the Society."
>
> "Our Society has been particularly fortunate in this, and much of its success has been due to the interest and cooperation of the individual member. It is this interest and cooperation that we wish to maintain, and we look to the members to continue in the building up of the Society's strength and usefulness."

There are many ways in which you can help to increase the number of members of the Society. Of these, the most important is personal solicitation of new members. Another way is to furnish national headquarters with the names of prospective members. If we had a larger membership we could increase the size of the JOURNAL and could do more research work and, in general, enhance the value and importance of the Society.

A TRUE STORY*

I went to the meeting of the Society last fall at Philadelphia. The first day I was there, not a soul spoke a single word to me and I went to bed that night damning the Society for a bunch of cold-blooded, high-hatters, or worse. I saw others talking vivaciously together, but they had no use for me—I was nobody. I made up my mind to go home on the first train the next morning.

However, in the morning I said: "I've been at some expense to come to this meeting and I'm going to stay one more day and I'm going to test this situation out. I'm going to speak to any one, *any one*. I don't care who it is, from the president down, that's wearing a badge, and see what happens." And I did.

I found the president just as willing to talk to me as anybody. I tried the past-presidents, and the vice-presidents, and the directors, and everybody I approached was in a happy mood, ready to talk technique, or to jolly, or to discuss the trips or the weather just as pleasantly and congenially as would my own brother. More so, in fact. Every one was on his toes, full of pep and ready to enjoy himself thoroughly. I stayed the week through and never had a better time in my life.

Toward the end of the week I spoke to a wallflower and found him just as I had been on my first day. He said I was the first man he'd met that had spoken to him and I took him in hand. I asked, "Want to meet the president?" and he replied, "Do you know him?" and I said, "Sure! Come on, let's go see him." And we did. Later, I told the wallflower what I'd learned during the week—that my stupid time was my own fault and that when I had done my share I had a bully time.

The above is as nearly as possible a verbatim account as told to one of the officers of the Society by a member who said his object in telling it was in the hope that it might be of help to others who felt themselves neglected by their fellow members in the Society.

*Taken from "Proceedings of the American Society of Civil Engineers," Dec., 1927.

INTERNATIONAL ACETYLENE ASSOCIATION MEETING

The Annual Meeting of the International Acetylene Association was held at the Stevens Hotel, Chicago, November 16, 17 and 18.

The meetings were presided over by W. A. Slack, Chicago, president of the Association. The officers elected for the year 1927-1928 were President, L. E. Ogden, Oxweld Acetylene Company, New York; Vice-President, L. F. Loutrel, Shawinigan Products Corporation, New York; Secretary-Treasurer, A. Cressy Morrison, New York.

Professor H. L. Whittemore of the U. S. Bureau of Standards outlined the testing work on welded pressure vessels and structural steel which are to be conducted at the Bureau of Standards and other places under the auspices of the American Bureau of Welding.

The subject of the relative efficiency of city gas and acetylene as fuel gas for cutting with oxygen was also discussed in two important papers.

The welding of large pressure vessels from 1⅛ in. steel plate was described in detail by H. E. Rockefeller, the Linde Air Products Company, New York. Mr. Rockefeller stressed the necessity for procedure control in work of this kind and outlined the stringent tests to which a number of pressure vessels built under his supervision were subjected.

R. M. Mock, New York, Technical Editor of "Aviation," described welded construction of aircraft.

W. B. Miller, Union Carbide & Carbon Research Laboratories, Inc., Long Island City, N. Y., in a paper on the "Mechanical Testing of Welds" described several new methods of testing welded specimens and welded structures and outlined some considerations for interpreting these tests.

W. H. Dreis, Dreis & Krump Manufacturing Co., Chicago, outlined methods employed by his organization in producing machine tools with bases and other parts fabricated by cutting and welding standard plate and shapes.

T. W. Greene, New York, described the "Shear-Vee Joint for Bronze Welding Cast Iron Pipe." This new development in pipe jointing promises to eliminate entirely all of the disadvantages of cast iron pipe with respect to tightness and permanency of joints, and a long series of tests in the laboratory and in the field seem to indicate that by the method outlined, and with the proper weld design, a bronze welded joint up to the full rated strength of the pipe itself can readily be produced. Mr. W. A. Lacke, master mechanic, Pullman Company, Chicago, described welding of their products in the Pullman shops and told in detail how the oxy-acetylene process was used in the construction of cars built by the Pullman Company.

FABRICATORS HEAR SECRETARY HOOVER

Reprinted from Oct. 27, 1927, issue The Iron Age

Novel use of a Victor talking machine was made by Herbert Hoover this month in an address delivered (in his absence) to the fifth annual convention of the American Institute of Steel Construction. His words were recorded on the instrument 11 days before its delivery on Oct. 25. The main portion of what he said appears in the following paragraphs:

"Each year has brought a closer approach to the achievement of your objectives and the fulfillment of the purposes for which the institute was founded. There has come about through your good offices a better understanding of the mutual problems of the steel fabricators and steel producers. Your effort to advance your industry through establishing standard codes of practice and ethics, and to take advantage of scientific and engineering research, is in line with the advancing vision of our great industries in their broader concept of service to the consumer, and thus to the public.

"This enlargement of vision, and this evident desire to be of service to the ultimate consumer, are outstanding developments of the post-war era of American business. It makes for greater stability in business and a greater public understanding of the purpose of business as a part of our whole cooperative nation.

"I was glad to see your interest in welding as a newer method of assembling steel structures. Your welding research program may yield some remarkable results and might even revolutionize steel construction methods. If the fellow who is laying a street car track outside this window with a pneumatic hammer only knew about it, I would be grateful right now.

"In any event, your effort is a practical step based on sound scientific research. Its success would promise economies in construction costs surpassing those already achieved by your work in simplifying and standardizing design. You have already accomplished much in this latter direction, and the further work which your association is doing in cooperation with the Bureau of Standards in the development of standard steel specifications is another sound step. Your work in the investigation of fire-proofing is still another service you are doing for the consumer."

SECTION ACTIVITIES

Chicago

The Chicago Section held its November meeting on Nov. 4 in the rooms of the Western Society of Engineers, Monadnock Building, at 7:30 p. m. The meeting started promptly, with about seventy present. The first two reels of the motion picture en-

titled "The Story of Steel," were shown. These pictures are very interesting, and cover the manufacture of steel from the digging of ore in the Minnesota mines to the heating of the iron billet in a soaking pit prior to rolling. The next two reels will be shown at the next meeting, and the last two at the meeting in January. Following these films, an address was given by Mr. W. A. Becker of the Haynes Stellite Company on the subject "Stelliting of Metal Parts for Resistance to Abrasive Wear." This was an exceedingly interesting address, and was followed by a lively discussion.

The secretary notified the Section of the Convention of the International Acetylene Association to be held at the Stevens Hotel, Chicago, and invited everyone to be present.

The December meeting of Chicago Section was held on the 2nd. The second two reels of "The Story of Steel" was shown. The speaker of the evening was Mr. J. B. Green, President of the Fusion Welding Corporation, who addressed the Section on the subject "A Study of the Flow of Welding Metal." Mr. Green has studied this subject in great detail and has developed in his laboratories some wonderful photographs and motion pictures. His lecture was illustrated both by stereopticon slides and by slow motion pictures taken with infra-red light which showed the actual transfer of the metal in both metallic arc and oxy-acetylene welding.

Detroit

The following is the program for 1927-1928 of the Detroit Section. All meetings will start at 8 o'clock sharp at the Detroit Engineering Society Clubhouse, 478 West Alexandrine Avenue.

NOVEMBER 30

Subject: Pipe Line Welding

Speakers

Fred Johnson, Vice-President, Johnson, Larsen & Co.

C. E. Phillips, District Manager, Purox Co.

M. L. Eckman, Superintendent of Welding, Ford Motor Co., Rouge Plant.

S. M. Harvey, Chairman.

—

JANUARY 6

Subject: Spot Welding of Aluminum

Speaker

Wm. Dunlap, Engineer, Aluminum Co. of America.

This will be a joint meeting with the Detroit Engineering Society. Come early and get acquainted. Bring a friend.

—

FEBRUARY 8

Subject: Production Welding

Speakers

M. L. Eckman, Superintendent of Welding, Ford Motor Co., Rouge Plant.

Albert E. Hackett, District Manager, Federal Machine & Welder Co.

G. F. Allen, Chairman.

—

MARCH 28

Subject: Structural Welding

Speakers

W. S. Wolfe, Structural Engineer, Smith, Hinchman & Grylls, Architects.

C. A. Daymude, Chief Engineer, Department of Safety Engineers, City of Detroit.

L. J. Knapp, Manager, Structural Division, Whitehead & Kales.

R. K. Slaymaker, Manager, Slaymaker Electric Welding Co.

R. G. Richards, Chairman.

—

APRIL 25

Subject: Replacement of Castings by Welded Steel

Speakers

M. J. Leonard, Superintendent of Tools, Chrysler Corp., Kercheval Plant.

D. H. Deyoe, Industrial Engineering Department, General Electric Co.

H. P. Doud, Chairman.

—

Bring Your Problems to the Question Box

The Question Box will be at the entrance door for every meeting. Drop your questions in the box, in written form. These questions will be answered and discussed the same evening. Such questions as are unanswerable at the time of reading will be carried over and answered at the next meeting.

Northern New York

A very interesting meeting of the Northern New York Section was held at the Ten Eyck Hotel, Albany, on Wednesday evening, Nov. 9. At 2 p. m. an inspection trip was made through the West Albany Shops of the New York Central Railroad. The building up of moving parts of locomotives, the repair of broken cylinders, welding of flues and many other interesting welding applications were

seen. Mr. J. G. Parsons, superintendent, welcomed the visitors to the plant before the start of the trip which was personally conducted by Mr. J. Weiss, welding supervisor of the shops.

At 6.30 p.m. about 50 members and guests had dinner at the Ten Eyck Hotel after which Mr. E. Wanamaker, electrical engineer of the Rock Island R.R. gave a very interesting talk. Mr. Wanamaker's remarks pertained to the general attitude toward the welding process and the work which he has done for the development of the process, in its application to railroad work. Mr. Wanamaker has been engaged in developing the application of welding since the days of the Emergency Fleet Corporation Welding Committee and his explanation of this work was very vivid and interesting. His plea for the support of the American Welding Society as the best method of self education and advancement of the welding process was very enthusiastically received.

Tentative plans call for three more meetings, one in Schenectady, one in Pittsfield and the last one in Albany. Inspection trips will be included in the program for each of these meetings.

Philadelphia

On Nov. 21 the Philadelphia Section held a meeting in the auditorium of the Engineers Club. This meeting was in the nature of an informal Symposium Covering Gas and Electric Welding. Addresses included: Mr. J. L. Anderson, Air Reduction Co., on "Factors Involved in Economical Gas Cutting"; Mr. J. W. Cattalane, Linde Air Products Co., on "Safe Handling of Welding Equipment," and Mr. T. C. Fetherston, Linde Air Products Co. The chairman, Mr. Thomas, talked on "Fitting the Generator to the Arc," and Mr. C. W. Bates discussed "Electrical Energy for Welding."

The Philadelphia Section holds its monthly meetings on the third Monday, in the auditorium of the Engineers' Club of Philadelphia, 1317 Spruce Street. The next meeting will be on Jan. 16.

San Francisco

The December meeting of the San Francisco Section was held on Monday, the 12th. Mr. Lincoln of the Lincoln Electric Co., spoke on "Application of Arc Welding to Replace Castings and Riveted Structures." The meeting was held at the New Engineers' Club.

New York

One of the outstanding meetings of the season was held as a joint meeting of the New York Section of the American Welding Society and the Metropolitan Section of the American Electric Railway Association. Posters from different parts of the world were on display. A very interesting travelogue was given of a number of foreign countries including England, Switzerland, Italy and also North Africa. Lantern slides were used to illustrate various points of interest.

The technical session was devoted to street railway welding. Mr. F. B. Walker, engineer, Maintenance of Way, Eastern Massachusetts Street Railway Co., described a new type of seam welded joint developed by his company. Mr. E. M. T. Ryder, way engineer, Third Avenue Railway Co., described some of the work of the Third Avenue Railway Co. and also gave an account of the work of the Welded Rail Joint Committee. The meeting was enjoyed by everyone present.

Boston

A meeting of the Affiliated Technical Societies of Boston was held on Wednesday, Dec. 14. A large number of welding papers were scheduled for this occasion. The following is the program:

MORNING SESSION—10:00

Chipman Hall, Tremont Temple, 88 Tremont Street, Boston, Mass.

Presiding—Frank B. Walker, chief engineer, Eastern Massachusetts Street Railway Co., Boston.

"General Principles of the Various Welding Processes"—F. M. Farmer, president, American Welding society, New York.

"Examples of Arc-Welded Steel Construction"—Gilbert D. Fish, consulting engineer, Westinghouse Electric & Manufacturing Co., New York.

"Welding Trusses for Industrial Buildings"—Andrew Vogel, General Electric Co., Schenectady, N. Y.

LUNCHEON—1:00

Auditorium, The Boston City Club, 14 Somerset Street, Boston

The Luncheon will be held under the auspices of the New England Water Works Association

AFTERNOON SESSION—2:00
Auditorium, The Boston City Club

Presiding—George A. Carpenter, president, New England Water Works Association; City Engineer, Pawtucket, R. I.

"Pipe Line Welding from the Oxy-Acetylene Viewpoint"—Le Roy Edwards, Industrial Engineering Department, Air Reduction Sales Co., New York.

"Pipe Welding and Other Recent Developments in Welding"—D. H. Deyoe, Industrial Engineering Department, General Electric Co., Schenectady, N. Y.

"Thermit Pipe Welding"—Robert L. Browne, New York and New England District Sales Manager, Metal & Thermit Corp., Boston, Mass.

"Replacing Castings by Steel Elements Cut to Shape by Automatic Shape Cutting Machines"—Dr. A. Krebs, treasurer, General Welding & Equipment Co., Boston.

"The Metallurgy of Welding-Wire"—C. A. McCune, director of research, American Chain Co., Bridgeport, Conn.

ANNUAL ENGINEERS DINNER
6:30
AUDITORIUM, THE BOSTON CITY CLUB
Under the Auspices of
THE AFFILIATED TECHNICAL SOCIETIES OF BOSTON
An Informal Dinner and Smoker
A Chance to Get Together

—

EVENING SESSION—7:30
Auditorium, The Boston City Club

Presiding—Lewis E. Moore, chairman, The Affiliated Technical Societies of Boston; consulting engineer, Boston.

"Unit Stresses and Reliability as Applied to Structural Welding"—Fred T. Llewellyn, representative of the American Society of Civil Engineers on the Joint Structural Welding Committee.

"Applications of Projection and Multiple Welds"—W. T. Ober, Thomson Electric Welding Co., Lynn, Mass.

"Reclaiming a Cast Iron Waterwheel Casing"—C. W. Babcock, sales engineer, Westinghouse Electric & Manufacturing Co., Boston.

"Atomic Hydrogen Welding Process"—P. Alexander, Thomson Research Laboratory, General Electric Co., West Lynn, Mass.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to Society headquarters.*

SERVICES AVAILABLE

A-65. Oxy-Acetylene Welder desires position. Have had eleven years' experience in oxy-acetylene welding. Was six years with the National Chain Co. At this plant had full charge of the welding and lead burning. There were forty buildings with all kinds of machinery to be cared for. For the past five years have been employed by the B. M. T. Corp. as senior oxy-acetylene welder. Am very much interested in welding.

A-66. Electric Welder desires position. Have had ten years' experience on tanks, shipyard repair, locomotive repair, structural steel, power plant, (water-dam), automobile repair and job shop.

A-67. Welder desires position. Have had thirteen years' experience. Have been with N. Y. Engineering Company, Welding Engineers, Inc., and Electric Welder Co. of America.

New Car to Embody Big Manufacturing Advance—Research Reveals New Uses for Welding*

Preparations for producing the new Ford car compose an industrial task which in magnitude and complexity surpasses any similar task the world has yet known.

In addition to their vastness and intricacy these preparations involve something more important and difficult. Ford engineering is making the introduction of the new car the occasion of an advance all along the line—in design, in materials, in construction, in production methods and machines.

By intensive experimentation Ford engineers have brought about almost revolutionary changes in certain manufacturing processes. Working along lines pursued by the company for the past ten years, they have extended almost a hundredfold the applicability of forged, stamped, and welded parts.

Five years ago the welding department worked eighteen months to develop a certain new welding operation and put it on a production basis. During the past twelve months the department, applying its cumulative experience, has solved at least thirty problems more difficult than that on which it once spent a year and a half.

"Welding," forty years ago, was done by the forging process. After electric welding had been invented, it was regarded mainly as a method of repairing broken objects. Far different has the meaning of the term become in the hands of Ford engineers, whose experimentation has been concentrated in the field of electrical resistance welding.

Heated to a high degree almost instantaneously by a heavy electric current, metallic objects, sometimes possessing quite different characteristics, are fused under pressure into a single piece. Allowance is made for burned edges, and the metal that is actually joined is fresh and unfatigued, making a weld as strong as, and sometimes stronger than, the metal surrounding it. The burned metal appears as a blackened ridge and is removed by machine. This is what takes place in butt welding, one of three types of electrical resistance welding. The same principle is carried out in the other two types, seam welding and spot welding.

It is electrical resistance welding that furnishes the key to construction and production progress. The possibilities of forging and stamping have been fairly apparent for some time past. But the problem of uniting forged and stamped sections as rapidly and as firmly as though they formed a single piece has prevented these potentialities being realized. For this problem electrical resistance is proving an effective solution.

*Taken from "Ford News," September 22, 1927.

Welder Co. of America.

Progress in electrical resistance welding is progress into the unknown. This is particularly true of butt welding, a type of resistance welding which finds wide and important application in the Ford industries. The worker in this field must begin with the idea and end by building the machinery to carry it out. There is, in nine cases out of ten, neither knowledge nor machinery existent to suit his purpose. Yet Ford welding, devising both theory and equipment as it goes, has made splendid progress.

Ten years ago there was hardly a welded part in a Ford car, and not more than three welding machines in the Ford industries. Then welding experiments began. When the final version of the Model T appeared on the market, it contained 212 welded parts, and there were more than four hundred spot and butt-welding machines employed in making them. In the new Ford car the number of welded parts will be increased by 90 per cent, or to more than four hundred, and the number of welding machines used in producing them will be increased to more than six hundred.

Of 302 spot-welding machines used in producing the Model T, it is expected that over 90 per cent will prove equally adaptable for production on the new car. On the other hand, hardly 5 per cent of the 104 butt-welding machines employed in Model T production can be used as they stand in manufacturing the new product. A greatly increased use of the seam welding process in connection with the new car has augmented the number of new welding machines being built in Ford plants or under Ford direction.

In every case where welding has been adopted it has made it possible to decrease weight without decreasing strength, and to lessen cost of manufacture without lessening quality. Further, it has immensely facilitated the accurate and precise adaption of the proper material for the proper part.

A seam weld is actually a succession of overlapping spot welds, usually made on a machine in which the object to be welded is drawn between copper disks placed edge to edge, through which the current flows. A seam welder bought by the company for production on the new car was discovered to make faulty welds. Examination revealed that the friction bearings of the copper disks allowed occasional interruptions of contact. The department devised and installed mercury bearings, which insure perfect contact.

Fifteen important features in all were redesigned by the Ford forces and ten of the units in which the changes were incorporated were ordered made. The makers of the original machine were willing to construct the new units, which were subsequently delivered under the name of the "Ford Special," in recognition of the redesigning they had undergone at Ford hands.

Aircraft Welding*

FRED P. SCHMITKONS†

In the pioneer days of airplane manufacturing, welding was an unknown process, so that planes had to be made with wood and metal fittings and wiring, thus making a death trap to the pilot in the event of a crash.

During the world war it was necessary to speed production on airplane production and it was at this time that welding was used to a great extent. Fittings that previously were riveted and bolted together were welded which gave them greater strength, also, increasing the production at the same time.

In the last five years, welding has played a major part in the great achievement of airplane records. For instance, the Spirit of St. Louis was an all metal fuselage with acetylene welded joints, thus proving that welded joints are stronger than wood and metal clips and wire that was used years ago.

The present day airplanes are more than two-thirds welded product. The main parts that are welded on an airplane are the fuselage, landing gears, tail surfaces and fittings, thereby giving greater strength, less weight and making the ship more compact and giving it a better appearance.

Some of the fittings that are welded and are used on the assembly of the fuselage have many duties to perform, such as, one of the main sections in the fuselage, the landing gear struts, the panel hinges, a support for an auxiliary gas tank which weighs more than 300 lb. with fuel.

The material used today in building planes has changed considerably from what it was five or six years ago. At that time, cold rolled sheet, Shelby seamless tubing made from low carbon steel was thought good enough for any plane construction, but, the research departments have shown us it would not stand the strains and stresses it had to perform in the daily use of speed planes of today. The only way this could be overcome was to use material of a greater strength; such as, mild carbon chrome molybdenum and chrome vanadium. These steels weld very readily with a low carbon wire. The best welding wire to my knowledge and with which I have had good results, is wire which conforms with the American Welding Society Specification G. No. 1A.

Considerable trouble has been encountered in the welding of these steels, mainly cracking and shrinkage and scaling.

In making a weld with chrome vanadium or chrome molybdenum, flat steel or seamless tubing, there are several things to keep in mind. First, at all times keep the torch properly regulated with a very slight excess of acetylene. Second, not to overheat the work. Third, do not handle the molten metal any more than is

*Paper presented before the Western New York Section of the A. W. S., on Oct. 20, 1927.

†Welding engineer, Curtiss Aeroplane & Motor Corp.

necessary in making the weld. There is one method that I have followed in the welding of fittings in airplane welding, that is, wherever there is a weld that ends at the outside of a fitting the weld should start at the center and work to the outer edges thus preventing a small check or crack. By doing this you are working expansion and contraction to the outer edges of the work.

In all welding there is a certain amount of strains and stresses built up that the naked eye cannot see, therefore, if the part that has been welded is small enough, it should by all means be heat treated; either quench and draw or normalize according to properties desired.

A very good practice in welding small fittings made of tubing with either plates or other small tubes welded to same, is to insert a piece of tubing inside of the tubing which is having the plate or tube welded to it. This helps to keep the scale from accumulating on the inside of the tube, thus keeping the proper thickness of wall of tubing and helping the bench mechanic in cleaning and reaming inside of tubes. It also helps to not overheat light tubing, such as .035 stock or other light tubing in the manufacturing of small fittings.

The majority of airplane fittings that are made are tacked in jigs and then removed and welded. Some of the larger parts such as engine mounts are welded in fixtures, welding one part and allowing it to cool before welding the other parts. This is done in order to overcome a great amount of shrinkage and thereby relieves a great amount of strains that otherwise would occur and cause considerable trouble in alignment of the finished product.

When welding the tubular all-metal fuselage all welding is done in an all-metal jig that is built of channel and tee iron, so as to be strong enough to keep the finished fuselage in perfect alignment.

The fuselage is made in three sections, known as the tail, center section and front section.

The tail section is composed of smaller tubing and thinner gage fittings, such as gusset plates and wire pulls, than the center section. The main upper and lower longeron tubes of the tail section are swedged to a smaller diameter at the front end so as to slip into the center section longeron tubes. These tubes are not welded but are hollow riveted.

Some places in the fuselage there are as many as five tubes meeting at one section. These joints are made by filing and fitting the tubes either to other tubes or to gusset plates or wire pulls.

The best results in welding an all-metal fuselage is obtained by using two welders on these sections, working directly opposite one another so as to keep an even heat on the different stations during the process of welding.

There are about six different stations in the center section of the fuselage and about the same number in the tail section. Each station is allowed to be free, that is, they are not tacked in place until they are actually to be welded, thus leaving the opposite end

of the tube that is being welded free so that it can go and come with the expansion and contraction during the process of welding, thus relieving any warping or shrinkage while being welded or allowing to cool.

Each station is allowed to cool before advancing to the next station to be welded.

The one main fact that is kept in mind when fitting and welding a fuselage is to have as close a fit as possible without forcing the tubes in place, thus helping the welder in overcoming the great amount of shrinkage he has to overcome.

The entire fuselage is welded in approximately twenty (20) hours by two welders, whereas it used to take three times as long and three times as many men to build one of the other fuselages.

The welder making welds on airplane parts should be an A No. 1 welder at all times and he should remember that upon each weld he makes depends the pilot's fate when he is flying the ship. It may mean his death due to an improper weld on the welder's part. The welder should be familiar enough with the torch he is using to know what size tips he should use, according to the thickness and shape of fittings he has to weld. Also the proper size wire that is required to make a satisfactory weld. For example: If a welder is making a weld on 1/32 in. stock, he should use 1/32 in. wire, not 1/16 in. or 3/32 in., as he would be overheating or burning his work before his wire would melt, or he would have more filler metal than he could handle properly, thus leaving a chance for an improper weld. I would like to say, at this time, aircraft welding is a great deal different from the general run of welding that is produced in light sheet metal production plants. The fittings and parts in the manufacturing of planes are very complicated at times, therefore, it requires great skill on the part of a welder to make a satisfactory weld. He also is required to make a neat appearing weld as well as a solid weld. There is no grinding or filing on the parts that he welds as this would tend to weaken the weld.

Brazing has been one of the main factors in building airplane parts from its pioneer days. We can divide the brazing method into four stages of development. First, by the open fire. Second, by the acetylene torch. Third, by natural gas and oxygen. Fourth, by dip brazing. The present methods that are being used today by aircraft companies that are working for government contracts, are dip brazing and by natural gas and oxygen. This work must be tacked close enough together so as not to warp out of place when being brazed, either by dip brazing or torch brazing. The acetylene-oxygen brazing has been discontinued by the U. S. Army and Navy as there is too much danger in overheating the work during the operation of brazing.

There are two different grades of brass used in brazing. In dip brazing they use what is known as 80-20 which is 80 per cent copper, 20 per cent zinc. This can be heat treated.

until they are actually to be welded, thus leaving the opposite end

In torch brazing with natural gas and oxygen they use 60 per cent copper, 40 per cent zinc. The parts brazed with this material cannot be heat treated.

All the copper oil lines and gasoline lines in the plane are silver soldered to brass or bronze fittings with natural gas and oxygen. All pipe lines are washed with hot caustic solution to remove the borax.

All aircraft welding or brazing is sand blasted and cadmium plated to detect any cracks or improper welding and also is given a very rigid inspection by the company's inspection and by the Navy or Army inspection.

The Use of Welding for Fabricating Roof Trusses

By WILLIAM DALTON†

A roof truss consists of two cord members latticed together by a system of tension and compression members which transfer the compression stresses to the top cord and the tension stresses to the bottom cord. So far it has been the usual practice to use a pair of angles both for the cords and connecting members, with gusset plates and rivets as the means of fastening the angles together. The use of rivets necessitates punching holes in the truss members and these holes cause a greater waste of material than merely that which is removed. The loss is equivalent to a strip of metal the full length and thickness of the member in which the hole is punched and as wide as the diameter of the rivet.

One-half of the connecting members are in compression and the other half are in tension. In compression, angles are not as efficient as H-beams but have been generally used because of the ease of making riveted joints with them. Tension members must be straight when applied so as to prevent a distortion of the truss under load. Channels are best suited for such tension members because they provide more metal directly in line with the applied load than any other section that has flanges to hold it straight.

This analysis indicates that if H compression beams can be economically fastened to channel tension members a truss can be made with the least amount of metal for a given load. It is not easy to rivet this combination of shapes together, but welding provides a means of making the necessary connections. It also avoids the loss of metal caused by rivet holes and does not require the gusset plates needed for riveted joints.

The welded truss design in Fig. 1 is a combination of H compression members and channel tension members which is flexible enough to accommodate the variations in the size of members required for the different parts of the truss. The cords are made of

†Manufacturing General Department, General Electric Company.

H-beams with flanges placed in the vertical plane. They can be reinforced at the center if necessary by welding extra plates to the webs. The tension channels are fastened to the outside faces of the cord flanges, and the H compression members are fastened to the inside flanges of the cords.

Seats for roof purlins are provided by plates welded to the top flanges of the upper cord. These plates are punched for the purlins

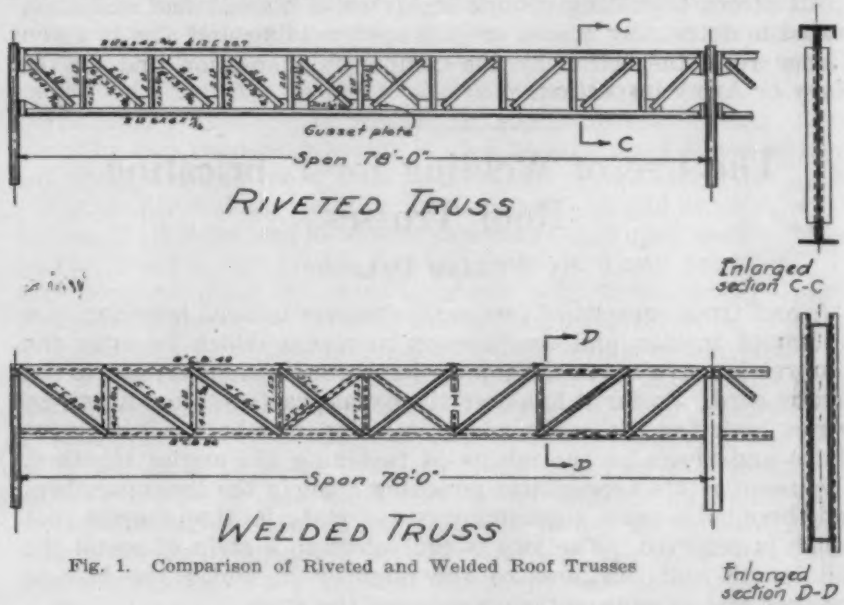

Fig. 1. Comparison of Riveted and Welded Roof Trusses

and give a connection to the truss without lowering the efficiency of the cord. Where sway bracing is needed, a channel is used for the purlin plate with its flanges turned down and punched for the diagonal brace rods.

A long series of tests has proved that a definite size weld of a given length made with a specified current and electrode has as definite and dependable holding value as a rivet. Skillful arc welders thoroughly equipped can make a cheaper connection than the riveted joint of equal strength.

The riveted and the welded trusses in Fig. 1 are designed for the same load and stresses. Riveted trusses are about 40 per cent heavier than the welded trusses, and bids received for both constructions show a considerable saving in cost by the use of the welded truss.

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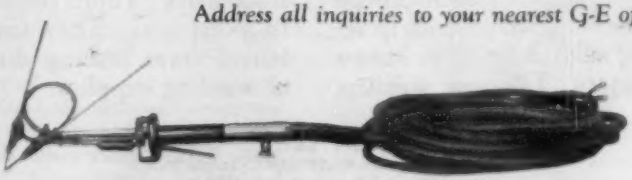

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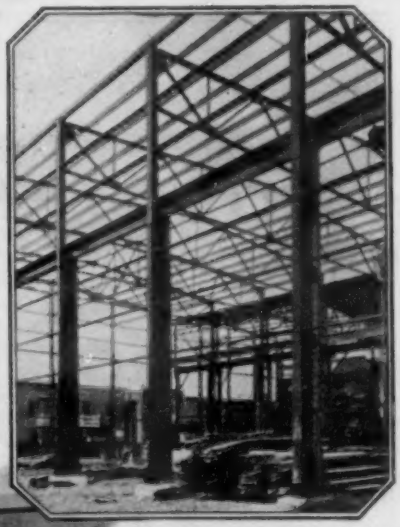

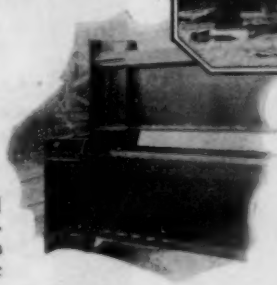

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CONTRACTORS and engineers in constantly increasing numbers are choosing electric arc welding for joining structural steel members. Its advantages have been demonstrated. It eliminates the necessity of punching holes and the use of rivets; it eliminates the din of riveting; it dispenses with many overlaps, brackets, and angle connections; it saves steel; it saves time; it saves money. And now in structural steel work, as in practically every other industry, Wilson Welding Wire demonstrates its superiority—its *uniformity*, its *smooth flowing* quality, its *economy*. There is just the right grade (analysis) of Wilson Wire for each kind of metal, and every grade runs *uniform throughout*—every rod is exactly like every other rod of the same grade. That makes *perfect* welds possible. "The rest is up to the welder."

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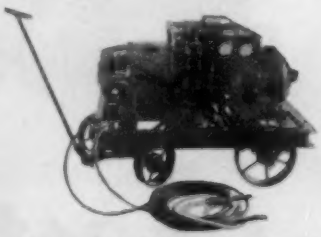

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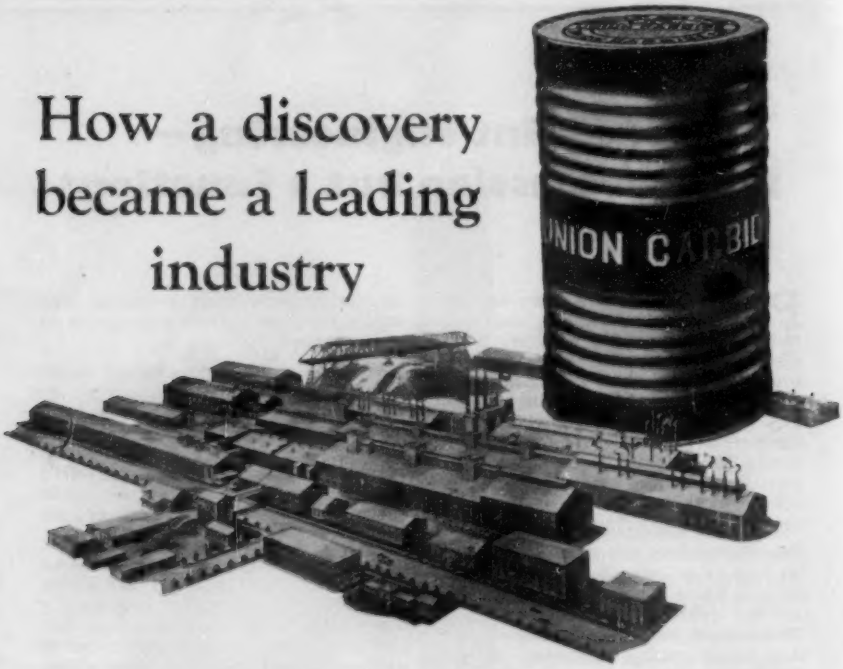

BACK in the early nineties a discouraged group of experimenters stood around an electric furnace. Time after time they had tried to produce aluminum without success.

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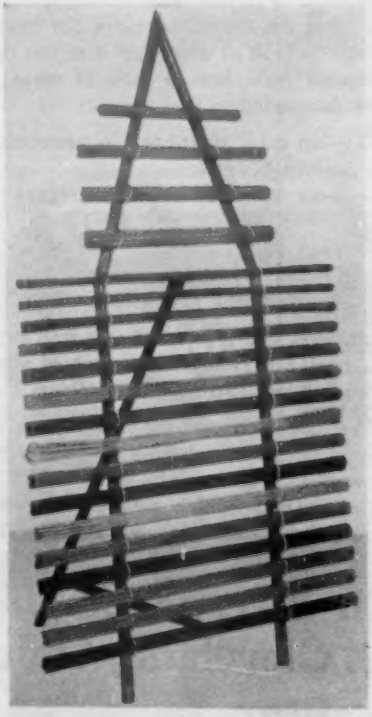

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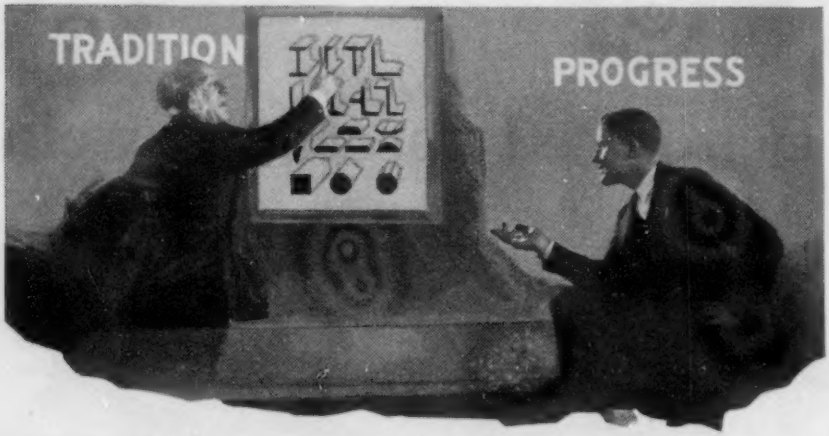

"Here, Lad—

All your recommendations that we adopt arc-welded shapes for economy and strength are necessarily aimed to oust cast iron from our manufacture. I don't like this because cast iron has been of wonderful service to industry. Look at all our designs that are descended from a long ancestry of castings."

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Even our own descent is a matter of conjecture. I see where a scientist says now that man's origin is traced to a primitive fish—which may explain why you can so often be all wet on the subject of welding."

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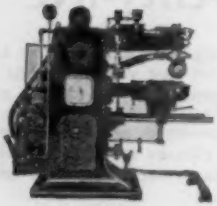

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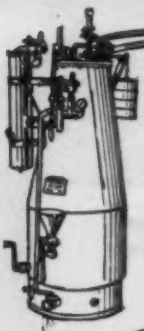

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ARC WELDING and CUTTING

Information and Instructions for the making of Arc Welds

Compiled by the Educational Committee of the American Welding Society as a source of reference of the fundamentals of arc welding

DECEMBER, 1927

Published by the

AMERICAN WELDING SOCIETY

29 West 39th Street

New York, N. Y.

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PREFACE

The three most important characteristics of a successful training program are: (1) a selected group of learners, (2) an occupationally competent instructor who has been trained in the art of teaching, and (3) functioning subject matter.

The American Welding Society has been engaged for a number of years in an attempt to promote the art of fusion welding through an adequate supply of competent welders. Several years ago it published in bulletin form an analysis of training courses for gas welders and for arc welders. These courses were prepared by representative committees, the members of which gave freely of their time and effort to the completion of these reports. These reports are known as Bulletin No. 4, Training Course for Oxy-Acetylene Welders, and Bulletin No. 7, Training Course for Electric Arc Welders.

More recently several sub-committees were created under the chairmanship of Mr. E. H. Ewertz for the purpose of preparing manuscripts on the fundamentals of welding and formulating the work of both committees into a manuscript which will serve as an authentic and up-to-date text for the training of welders.

The work of this Educational Committee was divided into four parts as follows:

Training Gas Welders and Cutters
Training Arc Welders
Training Resistance Welders
Training Thermit Welders

Each of these manuscripts was prepared by a sub-committee, the membership of which have endeavored to outline the latest and most successful practices in the welding process considered. This part deals with ARC WELDING AND CUTTING.

The American Welding Society is especially indebted to Mr. F. E. Rogers of the Air Reduction Sales Company, and to Mr. L. E. Ogden of the Oxweld Acetylene Company, for the manuscript on gas welding and cutting; to Mr. C. J. Holslag of the Electric Arc Cutting & Welding Company, and Mr. W. L. Warner of the General Electric Company, for the part dealing with arc welding; to Mr. H. A. Woofter of the Swift Electric Welding Company, for the part on resistance welding; and to Mr. W. R. Hulbert of the Metal and Thermit Corporation, for the part on thermit welding.

The Society is also indebted to Mr. James W. Owens, Director of Welding of the Newport News Shipbuilding and Dry Dock Company and Chairman of the Nomenclature, Definitions and Symbols Committee of the Society for his editorial work in connection with the nomenclature used in the manuscript.

Executive Committee

E. H. Ewertz, Consulting Engineer, 50 Church St., N. Y.
J. C. Wright, Federal Board for Vocational Education, Washington, D. C.
F. E. Rogers, Air Reduction Sales Company, 342 Madison Avenue, New York, N. Y.
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W. L. Warner, General Electric Company, Schenectady, N. Y.
L. E. Ogden, Oxweld Acetylene Company, 30 East 42nd Street, N. Y.

The manuscript presents the best knowledge available, not only from the welding standpoint but also from the standpoint of experience in preparing subject matter for training courses. All welding schools, both public and private, are urged to give it the most careful consideration and to use it as a text and guide in laying out proper courses for the training of welders. The arrangement of the subject matter is flexible and can be easily adapted to programs organized for the purpose of preparing new workers to enter this industry, as well as for the purpose of extending the technical education and skill of those already employed as welders.

CHAPTER I

ARC WELDING AND ITS POSSIBILITIES

Within the last ten or twelve years welding by the electric arc, oxy-acetylene, thermit and resistance methods has been accepted by industry as one of its most important production and repair processes. Formerly, welding was employed principally to repair broken parts of machinery and other metal parts, but until comparatively recent years, the value of welding as a standard method of joining metal pieces in general manufacturing was not fully appreciated. During the World War, however, the various welding processes came into their own rapidly because speed of production in every metal-using and metal-fabricating industry soon became a vital factor.

At first welding was limited to use on small or less important parts, but as favorable experience showed its dependability the field of application was gradually extended to heavier and more important construction and repair work. Many practical demonstrations of the utility of welding focused attention on its marked economic advantages with the result that now all welding processes are widely used in all branches of manufacturing. Welding is employed for an almost limitless number of applications from the manufacture of such small articles as watch-stems to the largest metal-fabricated structures—ships, locomotives, trunk oil and gas pipe lines, gas tanks and the largest turbine electric generators.

Development of welding applications was so rapid that the new art did not always show to the best advantage. The apparent simplicity of gas and arc welding led to its use by untrained workmen and in applications where the design of the joint between the parts to be joined or the nature of the material were not entirely adaptable to welding by the particular process used. Consequently some unsatisfactory work was done which resulted in delaying the day when engineers and the public at large were willing to accept welding with full confidence.

This condition was recognized by a number of far-seeing men interested in the conservative development of welding, and as a result, the American Welding Society was formed in 1919 for the broad purpose of putting the welding art on a sound, scientific and engineering basis. It was appreciated that only with such a foundation could welding ever be recognized as a thoroughly reliable process and be accepted for general employment in industry.

This Bulletin on Electric Arc Welding has been compiled by the Educational Committee of the American Welding Society so as to furnish a reliable source of information concerning the fundamentals of Electric Arc Welding to be used by student welders and engineers.

Arc Welding.—In Metal Arc Welding, the arc is formed between the parts to be welded and the welding wire, called an "Electrode." The parts to be joined are made one side of an electric circuit,

the other being the electrode. The power is usually supplied by a suitable transformer or by an arc welding generator which delivers an open circuit voltage ranging from 35 to 75 volts. The heat of the arc is sufficient to vaporize and melt the end of the electrode and this metal is transferred to the work. The heat is also sufficient to melt the surfaces of the parts to be welded which flow together with the added metal from the electrode and forms a solid homogeneous mass. A pool of molten metal is formed around the arc stream with a crater at the center. The arc is kept as short as possible in order to prevent occlusions of harmful gases and also to secure proper penetration. In the method known as Carbon Arc welding the electrode consists of a carbon or graphite pencil and additional metal if required is supplied by a metal rod which is melted in the arc. Metal and carbon arc deposits joining two steel parts closely resembles cast steel, as they are not ordinarily subjected to any mechanical working.

Welding may be done with direct or alternating current. The alternating current is usually supplied by a suitable transformer provided with proper taps in order that the welding current might be properly adjusted to the work in hand. Several types of direct current arc welding equipment are available. The generators may be either constant potential, constant energy or constant current types. An arc welding outfit consists of a welding generator or transformer, a control panel for varying the current a voltmeter and ammeter, proper lengths of cable, an electrode holder and a suitable shield or helmet for protecting the eyes of the operator. The source of power, such as an electric motor or gas engine, may or may not be supplied with the welding generator.

In order that the student welder and engineer may be familiar with the apparatus needed in arc welding and their functions the next chapter is devoted to this subject.

CHAPTER II

APPARATUS AND EQUIPMENT

THE ELECTRODE HOLDER

Purpose of the Holder.—The electrode holder for arc welding is a manual tool similar to a pair of pliers, the function of which is to hold the welding electrode firmly in any desired position and at the same time conduct the welding current to the electrode without injury or discomfort to the operator. The electrode holder furnishes a means of easily changing electrodes and should be such as to hold the electrode securely while the welding is going on without putting unnecessary strain on the operator's hand.

Mechanical Features of a Good Holder.—As the electrode holder is a manual tool it should not become unreasonably warm and also should be reasonably well insulated electrically from the circuit. The handle may become warm, if the current carrying parts are not

The parts to be joined are made one side of an electric circuit,

of sufficient electrical capacity to prevent overheating, or if the current carrying parts are too close to the holding part. The handle may also become unduly heated by conduction from the jaws of the holder which is usually heated to a high temperature by the electric arc radiation. The latter is the main reason for becoming unduly warm, and there are several methods of preventing this condition. The handle may be insulated from the current carrying parts or the holder may be made long enough so that the heat can not be conducted to it in any great quantity.

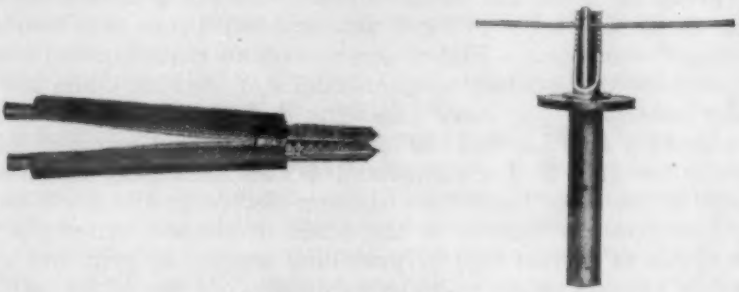


Fig. 1. Electrode holders

The holder should be reasonably light and balanced so that arc welding in any position may be easily done.

The ideal electrode holder is one which will release the electrode easily, grip it instantly and hold it until it is melted up to a stub about one inch long.

The Electrode Jaws.—The electrode jaws may be made of iron or steel, but some forms of manganese bronze may be preferable due to the fact that this material will not melt readily under the arc. Sometimes it is desirable that the gripping surfaces be removable so as to be easily replaced.

Some very simple grips can be made by splitting a pipe or having two closely fitting pieces hold the electrode between them, but these types of grips require such a stiff spring in the material that the electrode can not always be easily and quickly changed. For this reason they are sometimes inefficient from the standpoint of labor cost.

With the exception of a very few handles where the operator has to hold the grip tight, all handles have a spring arrangement to grip the electrode, and these springs must be so made or so located that they do not lose their temper from the arc heat. Those types that have no springs and depend on the operator to hold them tight are not popular with most welders, since this method introduces needless strain on the welder.

Changing Electrodes.—In nearly all electrode holders, there is provision for adjusting the electrode after its insertion in the jaws, as it is frequently desirable to change its position during welding. This adjustment is generally accomplished by sliding the electrode through the grip.

It is sometimes thought desirable to disconnect the electrode holder from the circuit while changing electrodes. This method appears to be best accomplished by means of remote control switches, or foot operated switches because the holder is likely to be clumsy if such circuit opening mechanisms are made a part of it. Ordinarily, however, the low voltage which is used for arc welding does not require these disconnecting devices just mentioned.

The names of the principal parts of any electrode holder are the gripping jaws, the handle proper, the cable connections, the hinge or pivot if any, spring if any, and heat protecting insulation.

Cable Connections.—Flat or screwed connections, tapered screwed connections and mechanical connections of various kinds are generally successful. In some cases the end of the cable is sweated into a socket at the end of the handle. A frequent cause of tangled cable is the fact that a right-handed man habitually revolves the handle in one direction when changing electrodes and a left-handed man revolves the handle in the other direction. Attempts have been made to correct this by providing a slipping grip, but so far the only remedy seems to be to straighten out the kinks once in a while.

A very important part of the holder is the first 10 or 15 ft. of the cable attached to it. This part of the cable should be very flexible so that the operator's arms and hand are not called upon to exert more force than necessary to manipulate the welding electrode, but at the same time should be large enough to carry the welding current without overheating.

The Parts of a Holder and Electrode Sizes.—The electrode holder should be so arranged as to be useful with any type of electrode in any reasonable size. The bare electrode and certain types of fluxed electrodes can be gripped at any point, while the flux coating of others wear out the gripping jaws due to arcing from poor contact. Heavily fluxed and "covered" electrodes are generally made bare at the ends or at the middle for gripping by the electrode holder. The sizes that would be called reasonable for an electrode holder to successfully handle vary from 1/16-in. diameter to 5/16 in. or 3/8 in. at the most. While there are larger electrodes used, other requirements would make necessary a special type of holder which would then take on the appearance of a carbon arc electrode holder. This holder is described under the subject "Use of the Carbon Arc for Cutting."

ARC WELDING APPARATUS

Construction and Operation of Arc Welding Apparatus.—Welding current can be obtained from any electric circuit of sufficient voltage, but usually a special low voltage machine is used in order to keep down the losses involved in reducing the voltage to the value required by the arc.

through the grip.

One of the chief functions of the welding apparatus is to supply the welding arc with electrical energy efficiently at the same time keeping the operator isolated from the main power line. The apparatus is so designed and built that the operator may adjust the energy of the arc to suit the job which he is doing.

Measure of Electrical Energy.—The current flow, which is measured in amperes, is caused by an electrical pressure which is measured in volts. The energy of the arc is measured in watts which is determined by the product of voltage by the amperage. The heat liberated by the arc is a function of the energy generated and, therefore, is dependent on the current and the voltage maintained across the arc.

Methods of Regulating Current Flow.—Some electrical generating apparatus is designed to furnish constant energy, i.e., to hold the product of the voltage and amperage constant. Other apparatus is designed to hold the current constant at the expense of voltage variation, while another type of apparatus is designed to hold the voltage constant at the expense of the current variation. These three types of electrical generating apparatus are respectively designated as follows: "Constant energy," "constant current" and "constant potential."

Various methods are used to regulate the welding current, such as (1) a dial switch in series with the armature or auxiliary field windings by which the coils may be cut out or cut in, (2) a brush shifting arrangement by which the excitation may be changed, or (3) a resistance in series with the generator. These are all methods commonly used to vary the current for the various welding needs.

The Arc Voltage.—The arc voltage for manual arc welding with a metal electrode is from 12 to 20 volts, depending on the skill of the operator, type of electrode, and the nature of the work which he is doing. The arc voltage when using the carbon electrode is about 40 volts.

The equipment used for supplying power to the welding arc may be a motor-generator set, as illustrated in Fig. No. 2, or a series-resistor for direct current welding. When alternating current is used for welding, the equipment may be a motor-generator set, series-resistor, reactor or transformer.

Historically, the first welding generators were designed with a shunt field only. In order to hold them to a reasonably steady output, an arrangement was made to cut in a resistance load equivalent to the arc load when the arc was not being used. This arrangement, of course, made the apparatus very inefficient in operation and required a motor of undue capacity. Even with such an arrangement no satisfactory balance of power could be maintained on less than 90 volts.

The next forward step was to lower the voltage by means of a compound field winding and by means of a clapper switch to keep down the "inrush" current. An improvement in this resistance-

value required by the arc.

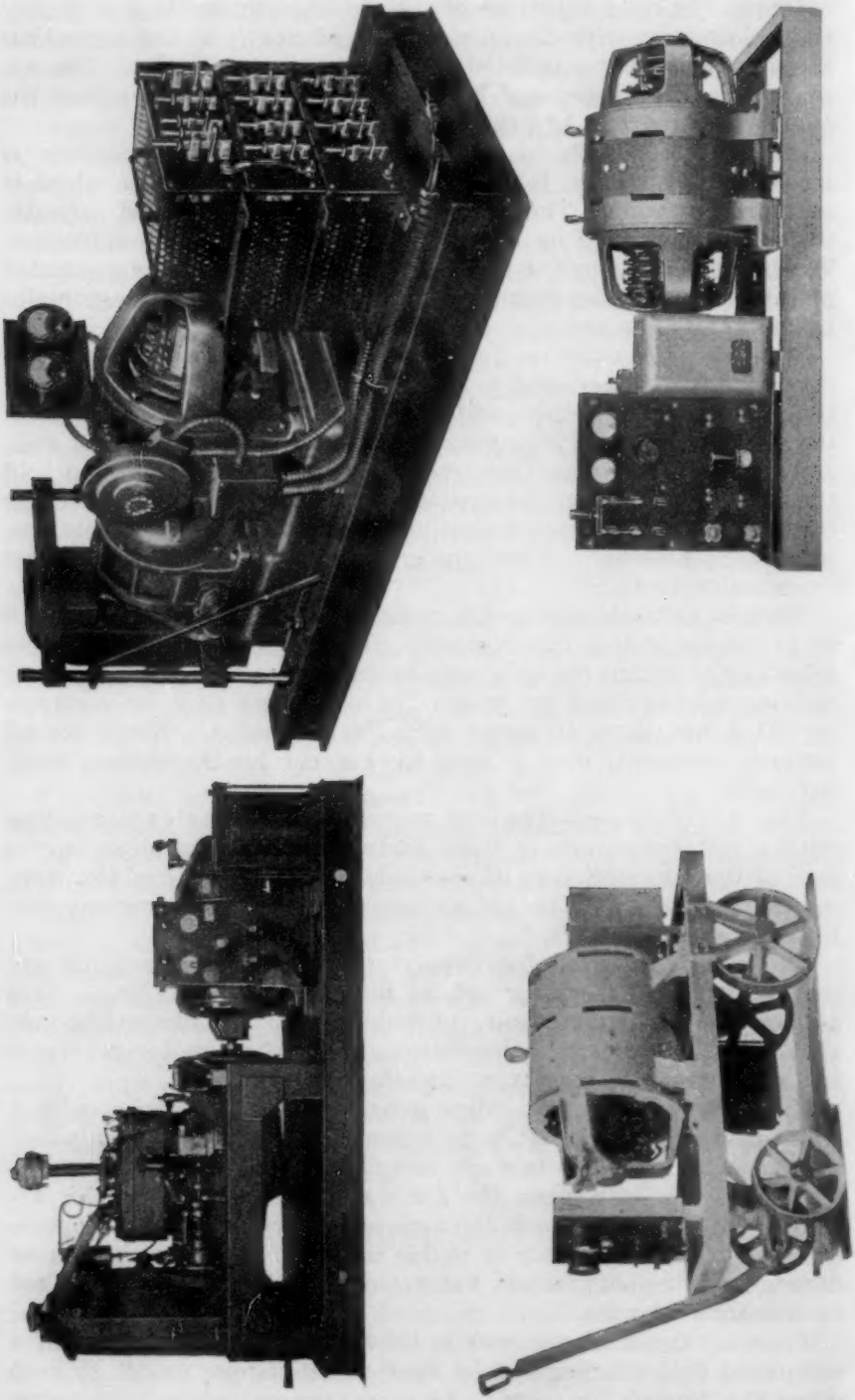
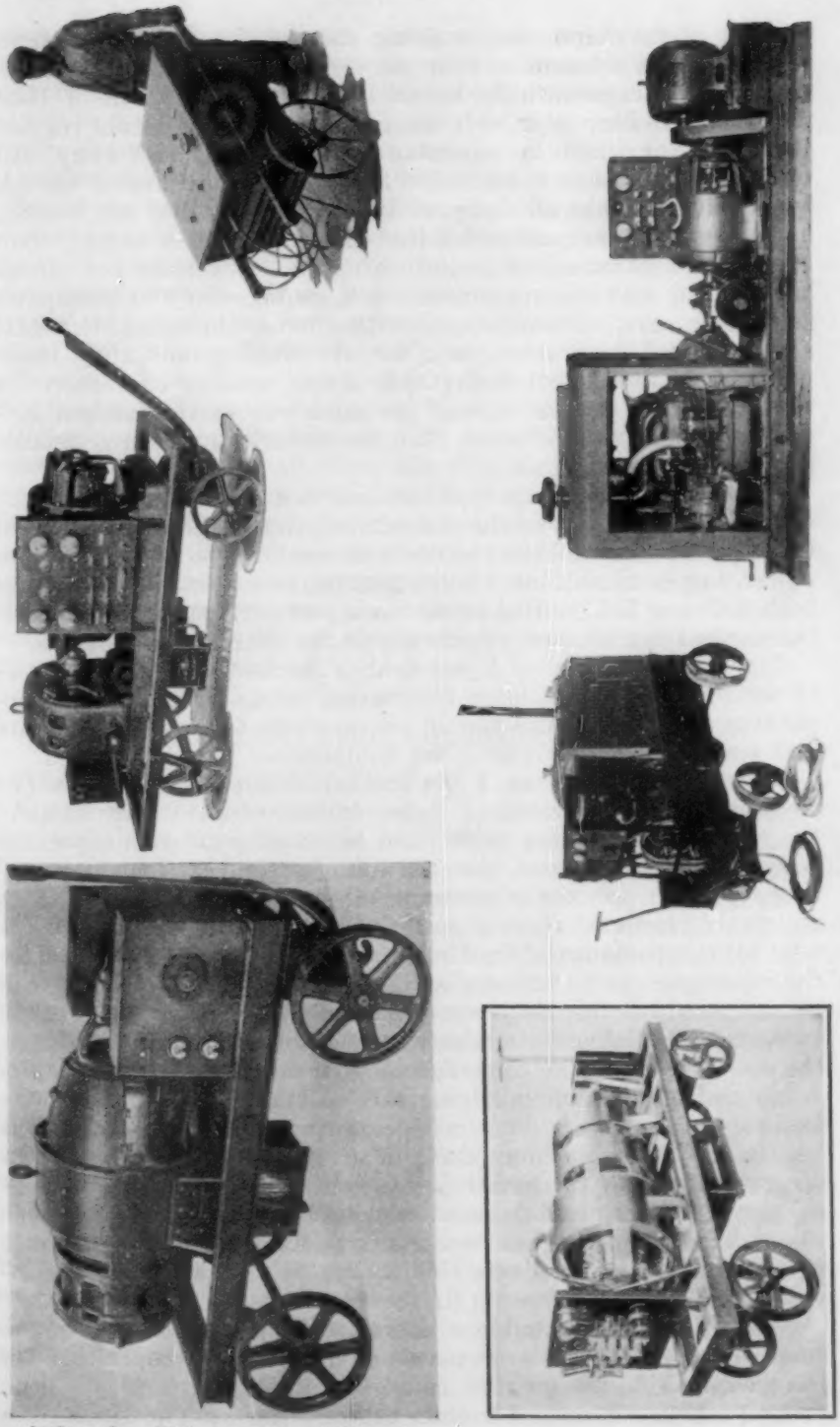


Fig. 2. A variety of stationary and portable

down the "inrush" current. An improvement in this resistance-



single and multiple operator welding sets

method of furnishing arc welding current was a live resistance operated by a solenoid so that the resistance was high on "short circuit" and automatically lowered when welding. All of these methods have been more or less superseded by the constant regulating generator which by means of a field control does away with most of the resistance control. These generators are of various types, but they are all designed primarily for metal arc welding and have such characteristics that the voltage dies under "short circuit" to a harmless value and maintains the welding arc voltage as required, and the open circuit voltage necessary to reasonably sustain the arc. Transformers with similar characteristics have also been put to practical use for arc welding and they incorporate a more efficient design and better welding characteristics than the series reactor type in the same way as the modern D.C generators are more efficient than the historically plain resistance apparatus formerly used.

There are also various combinations that are sometimes useful, such as a combination of the resistance type and the reactor type or transformer type and the resistor and reactor type to meet various power supply conditions. Some generators are made which give both A.C. and D.C. so that either the direct current or the alternating current can be used, depending on the character of the job.

Care and Operation of Equipment.—The various manufacturers of welding equipment issue instruction books covering their apparatus and these books should be carefully followed in the care and operation of any particular equipment.

Difficulties Due to Length of Cable and Loose Connections.—The welding arc voltage must be delivered between the electrode and the work. The welding cable must be so proportioned, especially when long leads are used, that the voltage drop between the generator set or other source of power and the arc is not excessive. With resistance regulated electric power sources the length of the cable is of little importance, if the Underwriters' rules are followed, since the resistance can be adjusted so that the necessary arc energy will be delivered to the electrode. With self-regulating generators, however, especially those which have a low open-circuit voltage, the size of wire in the cable becomes an important consideration. A simple computation involving the resistance of the cable wire and the current through it will show just how much voltage is lost in the cable and may explain an apparent reduction in the capacity of the power machine. A similar difficulty may arise in the power input side of the machine although this source of trouble is not so common. When working on jobs located at a distance from primary power plants this source of trouble should be investigated.

Another source of trouble with welding apparatus is that of too small power input leads or too small transformer capacity. On the welding side the greatest cause of voltage shortage is a poor ground connection or bad contact between the work piece and the

single and multiple operator welding sets

ground plate. This condition can generally be detected by the undue heating or arcing at the point in question. The difficulty hampers the welding operation because the energy available at the arc is sometimes considerably decreased by poor contacts or by poor connections which heat locally.

Carelessness on the part of the welder in dropping the electrode holder on the work piece is sometimes responsible for trouble with the power machine. Under these conditions the generator or transformer is generally put under full load and must satisfy short circuit requirements. This sudden load not only heats up the apparatus excessively but causes needless, excessive wear on every part of the system. If the short circuit is continued long enough an "arc-over" causing a short circuit in the windings of the machine may result because of burned insulation.

Difficulties When Machine Is Not Kept Clean.—The welding apparatus should be kept clean and free from dust and dirt as much as possible. Dust and dirt in the windings cause "arc-overs" and internal short circuits which seriously injure the apparatus. While the average commercial welding machine is built to stand rough usage and to operate in foundries, steel mills and industrial shops, nevertheless the increased life of the machine will usually more than pay for the little extra time consumed in cleaning and caring for the machine.

PROTECTIVE EQUIPMENT

Helmet and Face Shield.—The helmet, as worn by the welder in Fig. 3, is a shield to protect the operator's face, eyes, and neck from the direct light from the arc. It is preferably constructed of some insulating material, and provided with a window of protective glass through which the operator views the welding arc. It is designed to be supported from the operator's head, leaving both hands free, and generally is arranged so it can be tilted up on its support out of the way without entirely removing it from the operator's head. It should also prevent entrance of light from the side or rear caused by other welders. The color should be dark so as to reflect practically no light.

The material in the arc is at a very high temperature so that the light given out is intensely brilliant and contains a large proportion of the infra red and ultra violet radiation. This type of radiation is chemically active and will have very painful effects on the eyes and the skin. These radiations should be eliminated by the welder's lens used in the helmet and face shield which should also bring the intensity of the visible light down to a point where the glare will not injure the eyes. All glasses used should be subjected to a spectroscopic test before being allowed in the welding shop. The arc should never be observed without suitable protection to the eyes.

No chinks or holes in the helmet or face shield should be per-

mitted since only a brief exposure of the eyes to the direct rays of the arc is required to bring painful results.

Clothing.—A continual shower of sparks and globules of molten metal is thrown out by the welding arc. An apron of asbestos canvas or of leather, such as is worn by the welder in Fig. 3, will afford considerable protection to the welder's clothes, particularly in cases where the welder is sitting down while at work.

Gloves.—The skin of the hands while not as sensitive to the radiations from the arc as other parts of the body, nevertheless require gloves for protection. Gloves should be of leather and should be as flexible as possible without being so thin that they burn through easily. Gloves of inflammable material should never be used. The arms, neck, and face, however, should be covered since exposure of these parts will probably result in burns similar to sunburn, which though painful are not serious.

Screens and Shields.—When welding is to be done in a shop where others are working, screens should be provided to protect the eyes of the other workmen from the arc. These screens, as shown in Fig. 4 may also be used to protect the arc from drafts of air which interfere with its stability. Where small work is

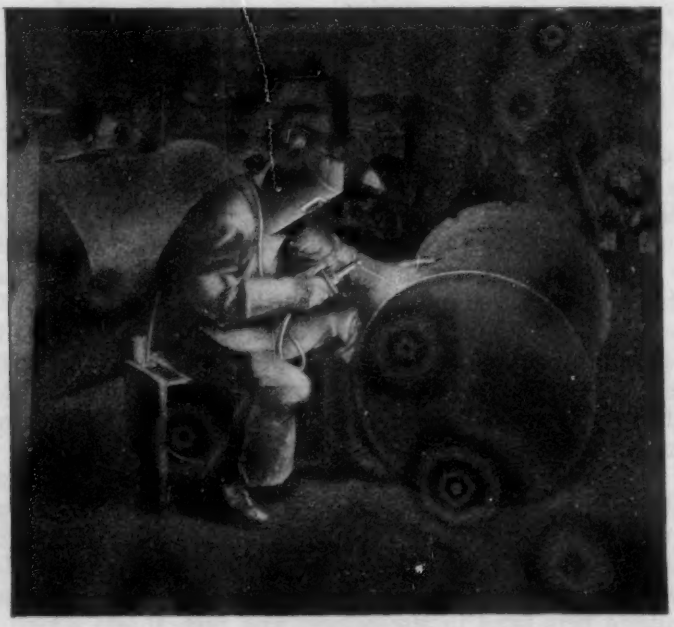


Fig. 3. Protective equipment for welding

being done, it is desirable to use a permanent construction in the form of booths or enclosures, one for each welder, but in the case of large work the screens may be portable. The material of which these screens are made may be ordinary canvas supported on any

No chinks or holes in the helmet or face shield should be per-

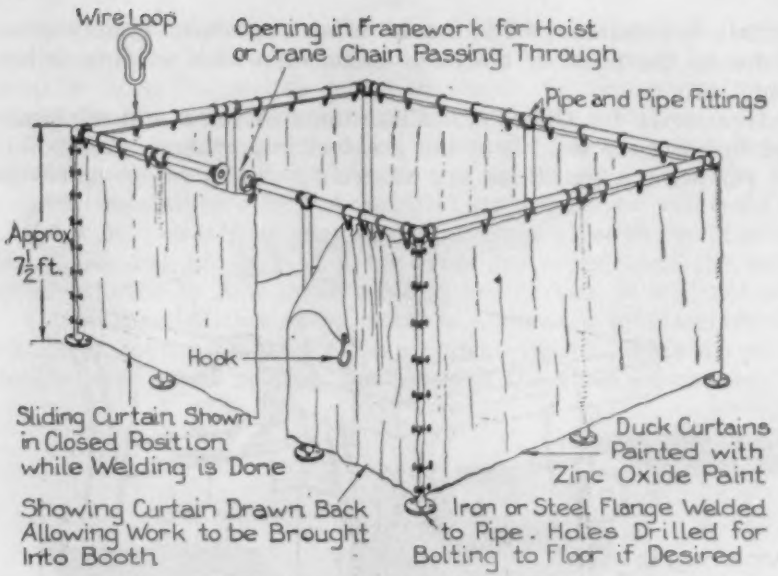

Wire Loop
Opening in Framework for Hoist or Crane Chain Passing Through
Pipe and Pipe Fittings
Approx. 7½ ft.
Hook
Sliding Curtain Shown in Closed Position while Welding is Done
Showing Curtain Drawn Back Allowing Work to be Brought Into Booth
Duck Curtains Painted with Zinc Oxide Paint
Iron or Steel Flange Welded to Pipe. Holes Drilled for Bolting to Floor if Desired

Fig. 4. Welding booth for protection of other workmen

desired form and painted a dull black to make it opaque and also to provide a surface on which the particles of hot metal will not catch.

ACCESSORIES

Welding Table.—For small work which may be picked up and moved about by hand, a welding table may be built of pipe fittings with a steel plate top to which the positive lead is connected. The work may be set on this bench, the contact being sufficient to carry the current. In many cases a vise mounted on the table will be found desirable. If the work is too large for the table, it may be set beside the table and a bar laid across to it. This will provide sufficient current carrying capacity, provided scale and rust do not entirely prevent contact, in which case the scale and rust should be removed by a file or peening hammer. Cast iron slabs provided with a large number of holes for fastening the work down so as to prevent warping are many times helpful.

Ground Connection.—For welding on a large work, a convenient terminal for the positive cable consists of a suitable clamp, such as shown in Fig. 6, of proper size to which the cable is bolted. The terminal may be laid on the work or hooked on a projecting part. It is seldom necessary to actually clamp the return lead to the work unless the metal is thickly covered with scale or dirt which acts as insulation, in which case it is easier to chip or brush off a clean place for the contact than to use a clamp, for which a place should also be cleaned. Care should be taken to see that good

contact is obtained. "The work" is an expression generally used to denote the piece or pieces of metal on which welding is being done.

Accessories for Cleaning.—Cleanliness of the metal adjacent to and forming the weld is of the greatest importance. Accordingly, the following suggestions are offered:

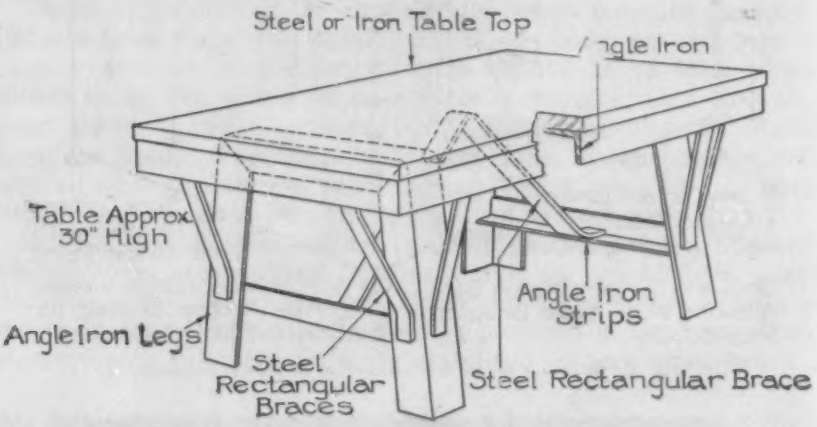


Fig. 5. A welding table

(1) *A steel wire scratch brush* may be used for removing light rust and scale and for cleaning between layers in heavy welds. A satisfactory brush is shown in Fig. 7.

(2) *A chisel* consisting of either a hand or air chisel should be used for removing heavy scale, slag from covered electrodes, or scale from oxy-acetylene cuts. The use of a roughing tool or a chisel having a cutting face, as shown in Fig. 18, is recommended by many for removing the scale. Great care should be taken to see that fragments of scale are not driven down into the metal by this tool. This frequently occurs and causes porous spots in the weld.

(3) *A sand blast* may be used for removing rust and scale, grease and dirt of all kinds.

(4) *Gasoline* may be used for removing grease or oil from machine parts. The metal near the weld should be well dried and the gasoline removed either by wiping or by the use of heat since the vapors given off interfere with the steadiness of the arc. Lye (caustic soda) may also be used as a cleaner.

Backing Material.—Carbon blocks may be used to prevent molten metal falling through when a weld is made from only one side. The metal will not adhere to carbon and a smooth appearance can thus be obtained. When carbon is used, metal next to the block will absorb a small amount of carbon and consequently will be harder than the rest of the material. The arc should never strike the carbon directly or this effect will be greatly increased. This

hardening effect should be considered if the surface is to be later machined. In building up pads, carbon blocks may be used as dams to keep the molten metal in place. Carbon sticks may be used to keep a hole open through a weld.

Copper may also be used for dams and backing, but the arc should never be allowed to touch the copper, otherwise the weld will be contaminated by the material, or the copper will weld fast to the work and will be very hard to remove after the weld is completed. If the arc is kept away from the copper and the molten metal allowed to flow down against the copper, it will not stick.

The welding of thin sheet metal is facilitated by clamping it to blocks of copper or steel with a copper insert. This serves the double purpose of holding the edges of the sheet in position and

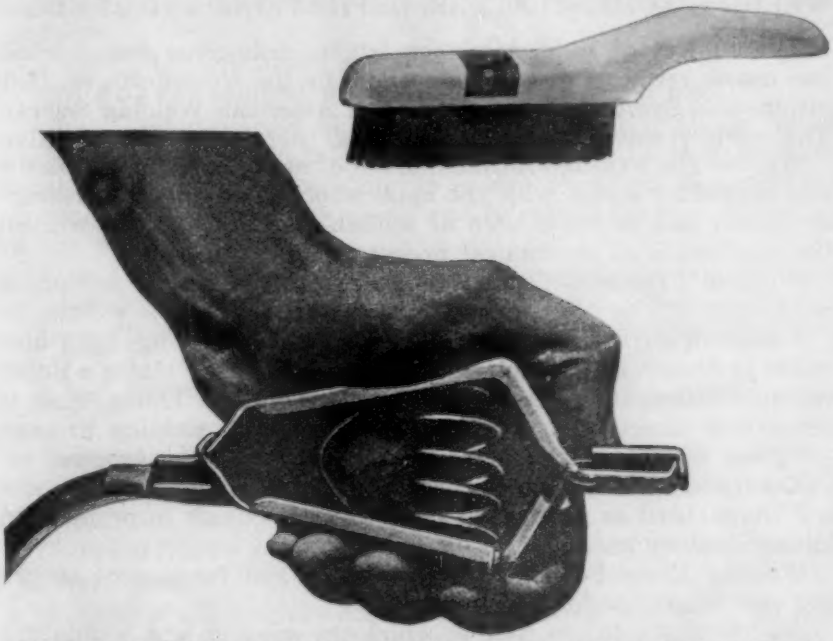


Fig. 6. Ground clamp for attaching lead to work. Fig. 7. A type of steel brush commonly used

it also carries away the heat and prevents burning through the thin metal.

Fire brick, asbestos and similar materials may also be used for molds and dams. Fire clay or carbon powder with sodium silicate as binder provides a convenient material for molding dams of special shape.

Cooling.—A supply of sand and asbestos paper is often useful to the welder. Some castings after welding should be cooled very slowly to relieve the strains due to the contraction of the metal. This is particularly true of complicated castings. The work may be placed in a box of dry sand and well covered with sand for from

one to two days. In the case of large pieces it is often satisfactory to cover the work thoroughly with asbestos paper.

Preheating Equipment.—Many castings should be thoroughly preheated before a weld is started, and in some cases the weld should be made while the heat is still kept on the casting. Gas and oil burners are used for this purpose. In some cases it is desirable to inclose the casting in a temporary oven of ordinary brick, built without cement, in order to heat the whole casting uniformly and in such cases the flame from the burner should not be permitted to play directly on the casting. Coke and charcoal are also largely used.

CHAPTER III

WELDING NOMENCLATURE, DEFINITIONS AND SYMBOLS

The subject of welding nomenclature, definitions and symbols has not as yet been adequately covered by the Nomenclature, Definitions and Symbols Committee of the American Welding Society. The **subject matter** of this section is, therefore, only **tentative.**

Weld.—The localized intimate union of metal parts in the plastic and/or molten states with the application of mechanical pressure or blows; and in the molten or molten and vapor states without the application of mechanical pressure or blows.

Welding Process.—The means or methods used to produce a weld.

Fusion Welding Process.—The method of welding by which welds are made in the molten or molten and vapor states without the application of mechanical pressure or blows. This process is sometimes incorrectly termed the "autogenous" welding process.

Fusion Weld.—A weld made by the fusion welding process.

Electrode.—A metal wire, carbon* rod or block of a definite size and shape, used as a terminal in an electric circuit to produce an intense heat by means of an electric arc.

Welding Rod.—Filler metal, in wire or rod form, used in gas and carbon arc welding.

Arc Weld.—A fusion weld in which the welding heat is obtained by means of an electric arc between the base metal and an electrode (sometimes between two electrodes).

Metal Arc Weld.—An arc weld in which the electrode used is a metal rod or wire, and which, when melted by the arc, supplies filler metal in the weld.

Carbon Arc Weld.—An arc weld in which a carbon electrode is used and filler metal, if required, is supplied by a welding rod as in gas welding.

Base Metal.—The material to be welded. Unless otherwise stated, it will be understood that a weld unites two pieces of identical metal.

*Carbon is a generic term and includes all modifications in structure, electrical conductivity, etc., due to manufacturing processes. Graphite is a form of carbon.

Filler Metal.—The metal which is added to the weld in some forms of the fusion welding process. In gas and carbon arc welding, it is supplied by a welding rod, in metal arc welding by an electrode, and in thermit welding by a thermit mixture.

Deposited Metal.—The filler metal which has been melted in the fusion welding process.

Weld Metal.—The material composing the weld and which has been melted in making the weld. In forge and pressure welding it consists entirely of base metal, while in fusion welding it may consist entirely of base metal; a mixture of base and deposited metal; or deposited metal and a mixture of base and deposited metal.

Root.—The bottom of a weld. In welds having intersecting fusion surfaces, the root of the weld is at the intersection of these surfaces.

Leg.—One of the fusion surfaces of a fillet weld.

Throat.—The shortest distance through the weld metal.

Flux.—Material used in welding to prevent the formation of oxides, nitrides, etc., in the weld and to eliminate those which have formed. In metal arc welding, it is also employed to retain the various elements of the electrode and to retard the rate of cooling of the weld metal.

Fluxed Electrode.—A metal electrode in which the flux has been applied either by dipping, spraying, painting or otherwise.

Bare Electrode.—A metal electrode which is not fluxed or covered.

Covered Electrode.—A metal electrode having an external wrapping or braiding of paper, asbestos or other material. A flux may be included with the covering.

Coated Electrode.—A metal electrode having a flux applied externally.

Sheathed Electrode.—An electrode having a flux between a metal core and sheath.

Composite Electrode.—An electrode having one or more conducting materials combined mechanically with the flux.

Electrode Holder.—A device used in manual arc welding for securely gripping the electrode and provided with a suitable handle and means for connecting the electrode to the source of electrical energy.

Face Shield.—A protective device for shielding the operator's face, neck and eyes, provided with a window having a protective lens and designed to be held in front of the face by the hand.

Helmet.—A protective device for shielding the operator's face, neck and eyes, provided with a window having a protective lens and designed to be held in place by the operator's head.

Manual Weld.—A weld made by an operator without the use of mechanical means.

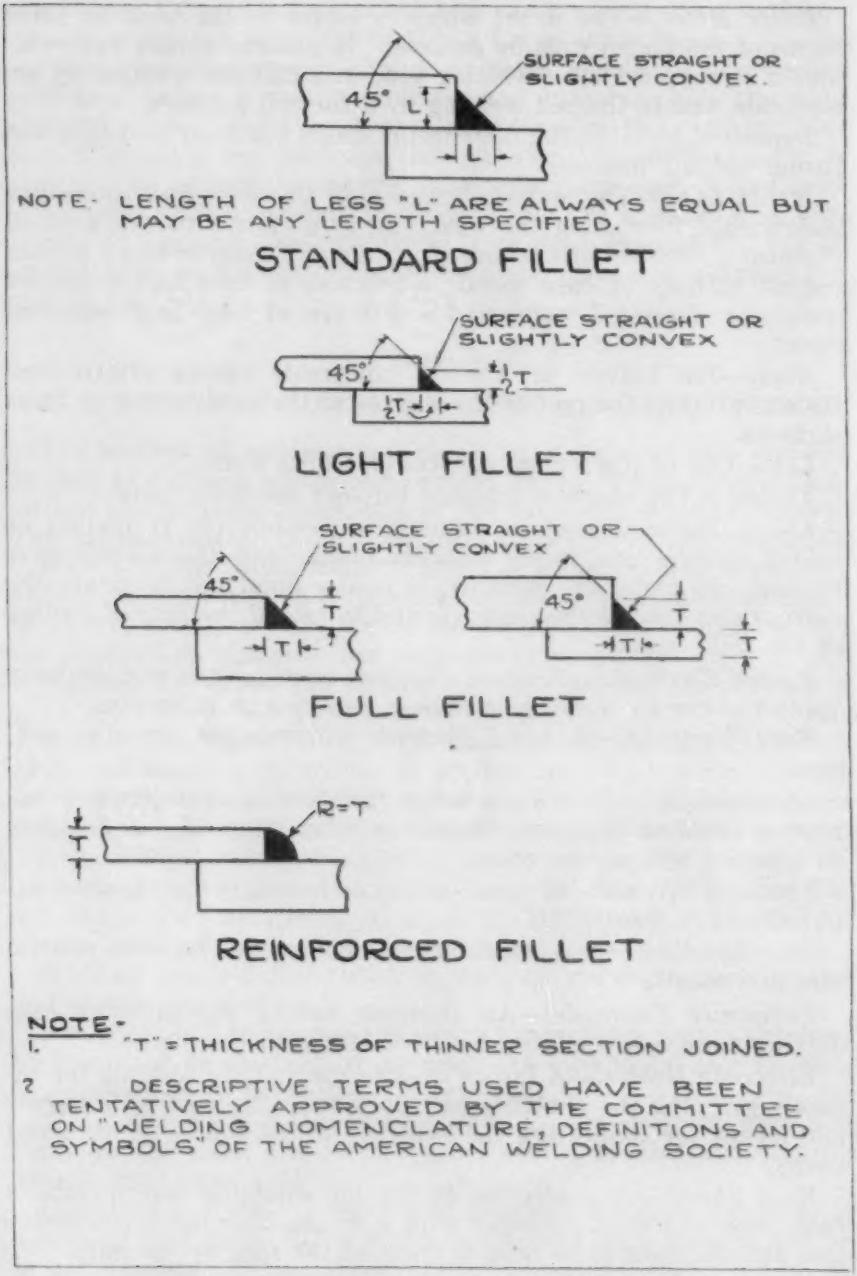


Fig. 8. Various sizes and proportions of fillet welds

Automatic Weld.—A weld made by automatic equipment.

Semi-Automatic Weld.—A weld made partially by automatic equipment and partially by manual means.

Full Automatic Weld.—A weld made entirely by automatic equipment.

Motor Generator Set.—An electrical device consisting of one or more motors mechanically coupled to one or more generators.

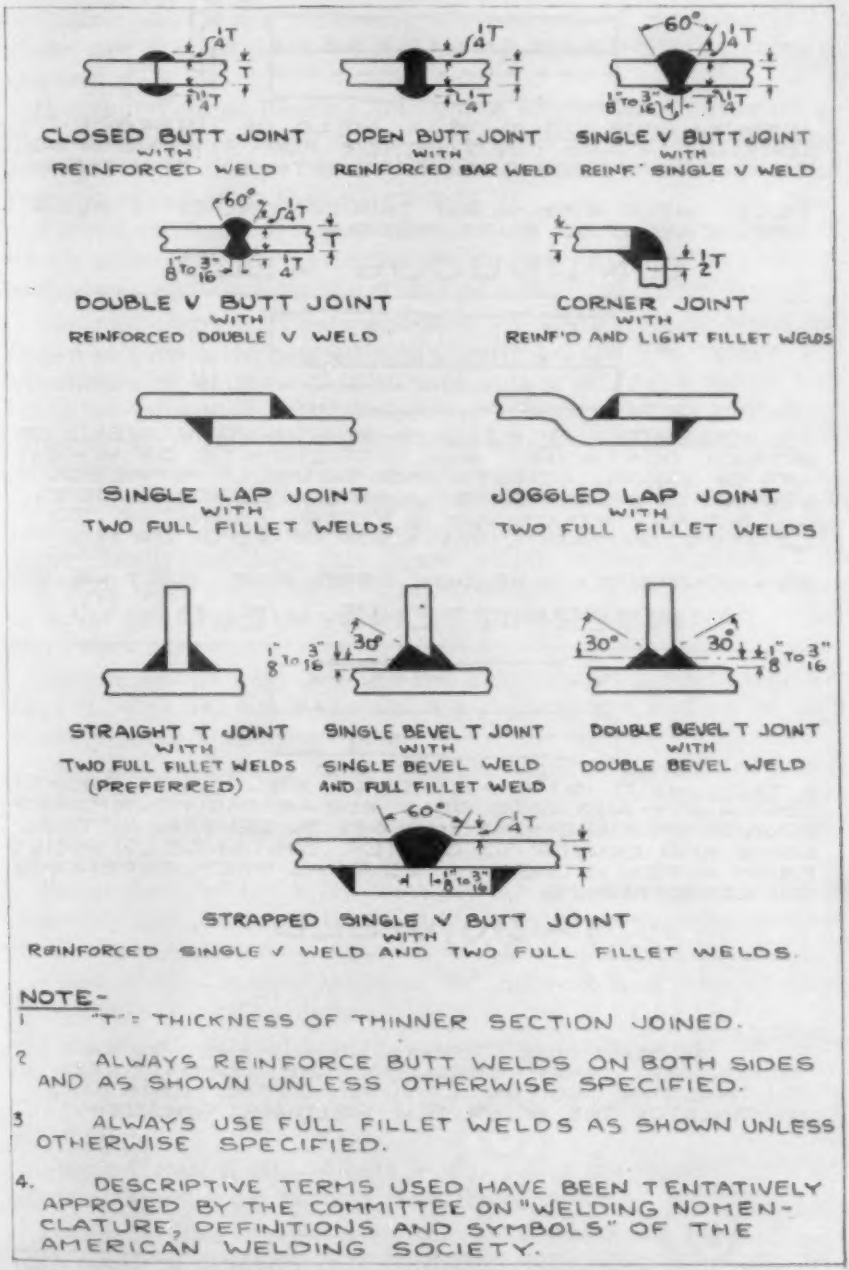

CLOSED BUTT JOINT WITH REINFORCED WELD
OPEN BUTT JOINT WITH REINFORCED BAR WELD
SINGLE V BUTT JOINT WITH REINF'D SINGLE V WELD
DOUBLE V BUTT JOINT WITH REINFORCED DOUBLE V WELD
CORNER JOINT WITH REINF'D AND LIGHT FILLET WELDS
SINGLE LAP JOINT WITH TWO FULL FILLET WELDS
JOGGLED LAP JOINT WITH TWO FULL FILLET WELDS
STRAIGHT T JOINT WITH TWO FULL FILLET WELDS (PREFERRED)
SINGLE BEVEL T JOINT WITH SINGLE BEVEL WELD AND FULL FILLET WELD
DOUBLE BEVEL T JOINT WITH DOUBLE BEVEL WELD
STRAPPED SINGLE V BUTT JOINT WITH REINFORCED SINGLE V WELD AND TWO FULL FILLET WELDS.
NOTE-
1 "T" = THICKNESS OF THINNER SECTION JOINED.
2 ALWAYS REINFORCE BUTT WELDS ON BOTH SIDES AND AS SHOWN UNLESS OTHERWISE SPECIFIED.
3 ALWAYS USE FULL FILLET WELDS AS SHOWN UNLESS OTHERWISE SPECIFIED.
4. DESCRIPTIVE TERMS USED HAVE BEEN TENTATIVELY APPROVED BY THE COMMITTEE ON "WELDING NOMENCLATURE, DEFINITIONS AND SYMBOLS" OF THE AMERICAN WELDING SOCIETY.

Fig. 9. Forms of joints in general use showing recommended methods of welding

Single Operator Motor Generator Set.—A motor generator set designed to supply current to only one welding arc.

Multiple Operator Motor Generator Set.—A motor generator set

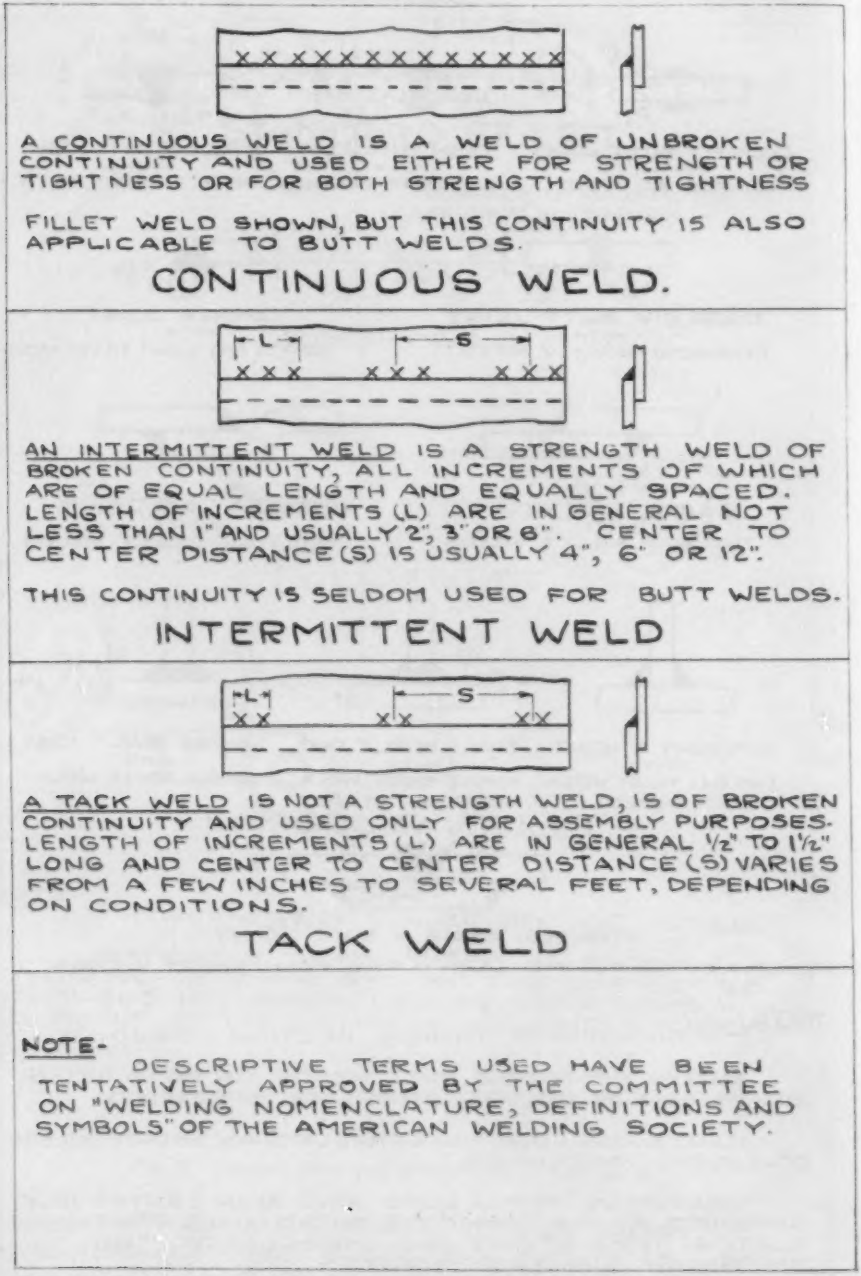

A CONTINUOUS WELD IS A WELD OF UNBROKEN CONTINUITY AND USED EITHER FOR STRENGTH OR TIGHTNESS OR FOR BOTH STRENGTH AND TIGHTNESS
FILLET WELD SHOWN, BUT THIS CONTINUITY IS ALSO APPLICABLE TO BUTT WELDS.
CONTINUOUS WELD.
L
S
AN INTERMITTENT WELD IS A STRENGTH WELD OF BROKEN CONTINUITY, ALL INCREMENTS OF WHICH ARE OF EQUAL LENGTH AND EQUALLY SPACED. LENGTH OF INCREMENTS (L) ARE IN GENERAL NOT LESS THAN 1" AND USUALLY 2", 3" OR 8". CENTER TO CENTER DISTANCE (S) IS USUALLY 4", 6" OR 12".
THIS CONTINUITY IS SELDOM USED FOR BUTT WELDS.
INTERMITTENT WELD
L
S
A TACK WELD IS NOT A STRENGTH WELD, IS OF BROKEN CONTINUITY AND USED ONLY FOR ASSEMBLY PURPOSES. LENGTH OF INCREMENTS (L) ARE IN GENERAL 1/2" TO 1 1/2" LONG AND CENTER TO CENTER DISTANCE (S) VARIES FROM A FEW INCHES TO SEVERAL FEET, DEPENDING ON CONDITIONS.
TACK WELD
NOTE-
DESCRIPTIVE TERMS USED HAVE BEEN TENTATIVELY APPROVED BY THE COMMITTEE ON "WELDING NOMENCLATURE, DEFINITIONS AND SYMBOLS" OF THE AMERICAN WELDING SOCIETY.

Fig. 10. Continuity of welds

Fig. 9. Forms of joints in general use showing recommended methods of welding

designed to supply current to two or more welding arcs at the same time.

Resistor.—A device possessing the property of electrical resistance. Resistors are used in arc welding circuits to regulate the arc amperes.

Reactor.—A device possessing the property of reactance. Reactors are used in direct current arc welding circuits to stabilize the arc.

Constant Voltage Welding Source.—A source which automatically maintains its voltage within 5 per cent of the rated full-load setting over the range from full load to no load and has a time of recovery of not more than 0.3 second.

Variable-Voltage Welding Source.—A source, the voltage of which automatically reduces as the current increases but not in such a way as to qualify the source as a constant-energy source.

Constant-Current Welding Source.—A source which, when adjusted to give rated current output with normal arc voltage, will automatically maintain this current output within 5 per cent of the rated value with a variation in arc voltage of 10 per cent above or below the normal arc voltage and has a time of recovery of not more than 0.3 second.

Constant-Energy Welding Source.—A source which when adjusted to give rated power output with normal arc voltage will automatically maintain this power output within 5 per cent of the rated value with a variation in arc voltage of 10 per cent above or below the normal arc voltage and has a time of recovery of not more than 0.3 second.

Butt Joint.—A joint in which two members are brought together edge to edge but not necessarily in contact, one surface of each member being in the same plane.

Butt Weld.—A weld which joins the edges or surfaces of a butt joint.

Lap Joint.—A joint in which the surfaces of two or more members overlap.

Single Lap Joint.—A lap joint having one overlapping surface.

Double Lap Joint.—A lap joint having two overlapping surfaces in the same plane.

Fillet Weld.—A weld made at the intersection of two surfaces of lap, corner, and tee joints.

Plug Weld.—A weld joining one member to another by the filling in of a hole in one of the members.

Tee Joint.—A joint in which the members form a T, usually at right angles.

Single V Butt Weld.—A butt weld in which the joint edge of both abutting members is beveled from the same side.

Double V Butt Weld.—A butt weld in which the joint edge of both abutting members is beveled from both sides.

Closed Butt Weld.—A butt weld in which the joint edges are straight and in contact.

Open Butt Weld.—A butt weld in which the joint edges are straight and spaced apart a distance, usually equal to the thickness of the thinner member joined.

Single Bevel Weld.—A weld in which the edge of one abutting member is beveled from one side. Used in butt, tee and corner joints.

Double Bevel Weld.—A weld in which the edge of one abutting member is beveled from both sides. Used in butt, tee and corner joints.

Strength Weld.—A weld having a predetermined design value and primarily intended to secure a mechanically strong joint. Its continuity may be either continuous or intermittent.

Caulking Weld.—A continuous weld primarily intended to secure tightness.

Composite Weld.—A weld complying with the requirements for both strength and caulking welds.

Flush.—A term applied to the exposed surface of butt welds when the surface is even with the surfaces joined.

Concave.—A term applied to the exposed surface of welds when the surface is depressed.

Reinforced.—A term applied to the exposed surface of welds, when convex or raised above the surfaces joined.

CHAPTER IV

THE WELDING ARC

The Electric Welding Arc.—An arc is formed by current flowing across a gap in an electric circuit. While the arc exists a small amount of the material, forming the terminals of the arc gap, is heated to an incandescent vapor. This vapor provides the material in the arc stream by which the current passes from one terminal to the other.

The terminal from which the current passes to the arc when direct current is used is termed the positive terminal, or anode, and the terminal to which the current passes from the arc is called the negative terminal, or cathode. The exact distribution of the heat in the arc between the two electrodes and the arc stream is still unknown. It is, however, a matter of general knowledge that the greater portion of the total heat of the arc is liberated at the positive electrode.

When direct current is used, one terminal remains as the positive continually and the greater portion of the total heat is liberated at this terminal. When, however, alternating current is used, the terminals are alternately positive and negative so that approximately the same amount of heat is liberated at each term-

inal. In direct-current welding circuits the positive is usually called the ground lead or ground terminal.

Polarity.—Usually the piece of metal to be welded is considerably larger and has more mass than the electrode so that the loss of heat at this point will be greater due to its being conducted back into the body of the metal. Consequently, it is desirable to have more heat liberated at this point to make up the losses and to bring the temperature of the metal to the fusing point at the

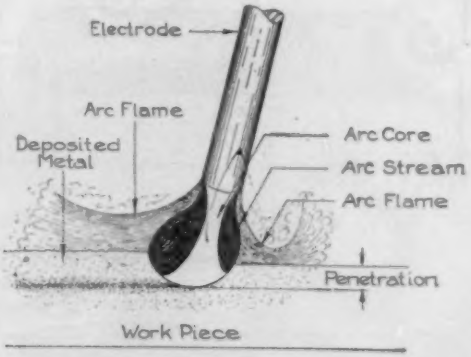


Fig. 11. Diagram of the welding arc

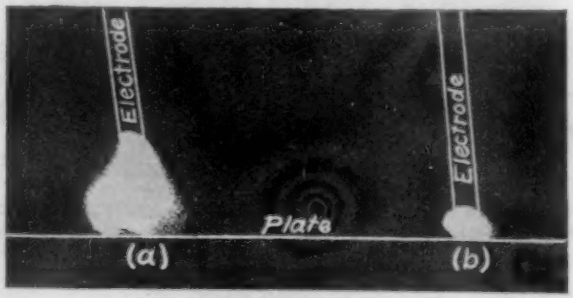


Fig. 12. Long and short welding arc, long arc stream causes excessive oxidation

same time that metal is fused and deposited from the electrode. In the welding of iron or steel the piece to be welded is usually made the positive terminal of the arc. In case, however, very thin metal is being welded, it is frequently advisable to reverse the polarity to prevent the arc burning through the metal. In the welding of some metals, such as manganese steel and bronze, it is often necessary to reverse the polarity and make the electrode positive.

Determining Polarity.—The polarity of a circuit can be determined in a number of ways. The simplest and most positive way is to determine it by means of a voltmeter. Another method is to draw an arc between either a bare metal electrode or a carbon

electrode and a steel plate. If the plate is positive and the electrode negative, the arc will be fairly stable. If, however, the circuit is reversed and the electrode is positive, the electrode will heat up very rapidly and the arc will become "wild" or it will flutter and will be hard to keep going. With reversed polarity the

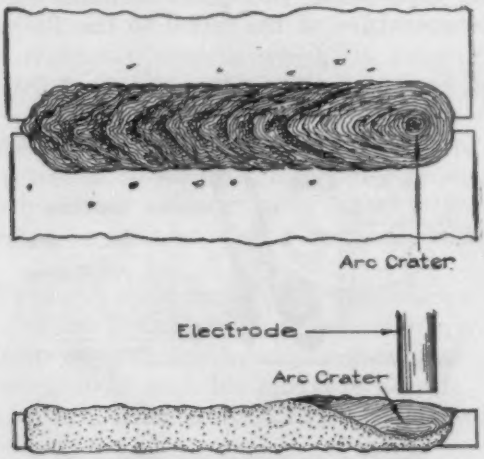


Fig. 13. Longitudinal section of deposited metal showing penetration and arc crater

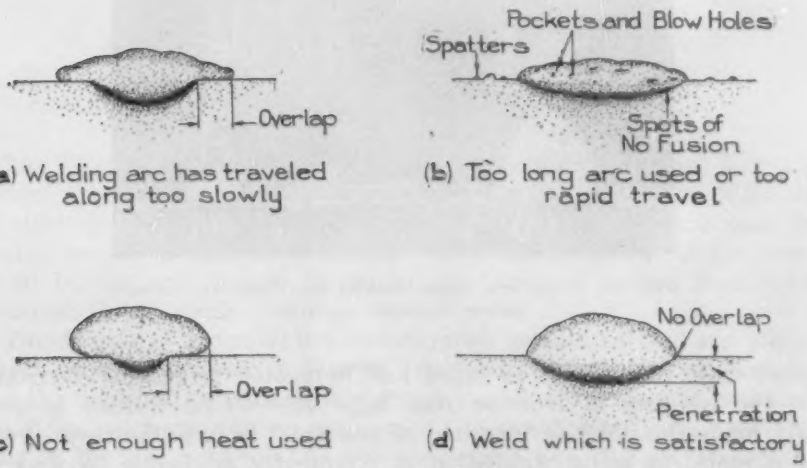


Fig. 14. Cross sections of beads deposited under different conditions

penetration with the average steel electrode is poor and the deposited metal can be very easily knocked loose.

Characteristics of the Welding Arc.—The temperature of the vapors in the arc and, consequently, the intensity of the light given out is so great that darkened glass must be used in order to observe the arc. When suitable glass is used, the different portions

draw an arc between either a bare metal electrode or a carbon

of the arc can plainly be distinguished from one another. The center of the arc is usually referred to as the arc core and some observers are able to see that this is divided into two portions designated as "arc core" and "arc stream." In general, this portion of the arc will usually be seen as greenish in color, of comparatively small diameter and forming a direct line between the two terminals of the arc. The point where the arc core strikes on either terminal is seen as a light red or yellowish spot, considerably bright, and, therefore, hotter than the metal surrounding it. The metal around this spot is molten and is usually seen as a bright red area.

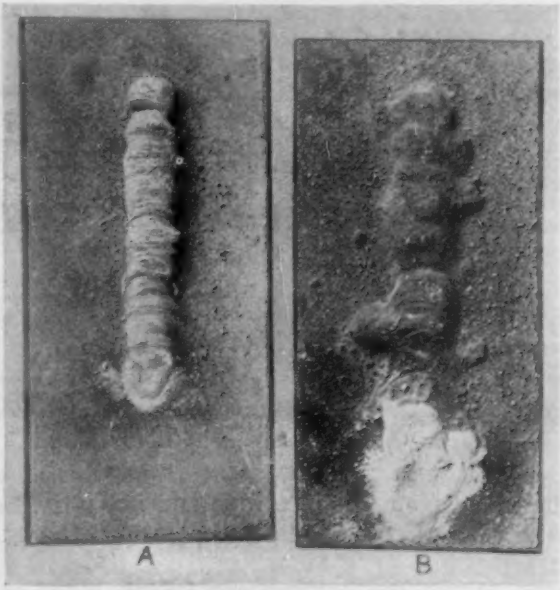


Fig. 15. Deposits obtained with short arc and long arc. Note that surfaces of deposit and plate in (B) are heavily coated with iron oxide, while those in (A) are comparatively clean

This color gradually shades off into a darker red with lower temperatures and finally becomes black at a short distance, not over ½ in. from the arc, except in the case of very heavy welding. Slag and oxides can be distinguished floating on the molten metal either as light or dark spots, depending upon the melting point of the impurity. Surrounding the arc core is the arc flame which is irregular in shape and in constant motion, being easily deflected by magnetic fields due to the current in the electrode and in the plate and also by drafts which may arise by reason of the heat in the arc or by exposure to wind.

Penetration.—The metal is melted at the point where the arc strikes the plate, assuming that the current, polarity and speed of travel are correct, and seems to be forced out of the pool by some sort of blast from the arc. This results in the metal piling

up around the edges of a small depression when the metal is in a molten state. This depression is referred to as the "arc crater," as shown in Fig. 13, and its depth provides a means of observing the penetration during welding and, to a certain extent, of predicting the soundness of the weld since one requirement of a weld is to secure good penetration. The crater depth will depend upon the thickness of metal welded, but in general should be at least 1/16 in.

Correct penetration will make certain that the metal of the plate is melted and in condition to receive the metal projected from the electrode, also that the area of the crater will be sufficient to

Fig. 16. Overlap and penetration studies. (a) Typical section through a normal layer formed by depositing metal from a mild steel electrode on a mild-steel plate. Note the contour of the deposit as well as that of the fused zone and the slight overlap and correct depth of deposit penetration. Parent metal crystal structure is altered by thermal changes. (b) Typical section through a deposit formed when holding a long arc. Excessive overlap and no penetration exists. Many weld failures may be attributed to the operator maintaining occasionally or continuously too long an arc. (c) Section through crater formed on completing deposit strip. The depth of the crater is a measure of the depth of penetration

receive all the metal from the electrode and not permit any of the deposited metal to overlap on the solid metal of the plate where it will not fuse.

Arc Length.—While the correct arc length alone will not insure good welds, it is agreed that a long arc is almost certain to result in a poor weld. The plate or work is heated by the release of energy at the terminal of the arc, by radiation and conduction from the arc core and stream, and by radiation from the hot surface of the electrode and the hot metal deposited on it. With a short arc this heat is concentrated on the plate, whereas with a long arc a great deal of it is lost into the surrounding space. consequently, with a short arc a greater portion of the energy is transformed into useful heat.

A long arc is not as stable as a short arc and tends to wander about over a considerable area on the plate and the arc flame blows about very rapidly. This action together with the greater length of the arc, affords considerable opportunity for the air to come in contact with the metal passing from the electrode to the plate and also in contact with the very hot metal in the arc pool or crater. This results in the absorption of oxygen and nitrogen, both of which are detrimental to the quality of the weld. With a

some sort of blast from the arc. This results in the metal piling

short arc, the flame consisting of vapors coming out of the arc acts as a protection and prevents very largely the absorption of these outside gases.

Conditions of Voltage Across Arc for Metal Electrode Up to 3/16" Dia.

Conditions	Bare Wire	Half Coated	Full Coated	Heavily Coated
Close arc (overhead work)	11 to 15	15 to 22	23 to 25	27 to 32
Medium close (good arc)	13 to 18	20 to 25	24 to 28	30 to 35
Medium long (poor arc)	17 to 20	23 to 27	27 to 32	33 to 38
Long arc	20 to 25	26 to 30	30 to 35	36 to 48

Stable and Unstable Arcs.—It has been found that the welding current flowing in the electrode under some conditions sets up a magnetic field causing the arc to become wild. Slanting the electrode forward or backward has an effect on this condition. The path of the current in the work also occasionally causes this

a b c

Fig. 17. Overlap and penetration studies. (a) Excessive overlap secured with a pencil electrode (drill rod) having a lower melting temperature than the parent metal (mild steel). (b) Elimination of overlap obtained by using a pencil electrode (mild steel) having a higher melting temperature than the parent metal (cast iron). (c) "Cutting" secured through use of high arc current

trouble. Generally speaking, one welds away from the ground connection but sometimes a change in the location of the ground connection will eliminate undesirable magnetic fields and the arc will become steady.

Steam or vapors will make an arc unstable and may cause it to go out frequently to the detriment of the weld. Such a condition might arise in sealing a crack in which some oil or water remains. As the metal is heated this matter turns to a vapor and rises through the crack into the arc.

CHAPTER V

THE ELECTRODE

The welding profession generally is rapidly reaching the point where it recognizes that the best practice requires the use of first-class welding materials as electrodes, and not just any

piece of iron wire which will melt. The weld, after it has been melted by the arc, consists almost entirely of the electrode and the welder can no more secure the best results with a poor electrode, however great his skill, than he can make a first-class steak from an inferior cut of meat by skillful frying. The appearance of the weld might be good but the quality will be considerably better if the electrode is the best obtainable for that particular weld.

It is a false economy to attempt to save on electrode cost in view of the fact that, while during a period of ten years the cost of the welding machine and the cost of electrodes might together amount to the sum of $3,000, the labor cost for proper usage of this equipment and supplies would be from $20,000 to $30,000. Under these conditions any time lost in duplicating work done with a poor electrode adds much more to the labor cost than the small saving which might be effected in electrode cost. The best electrode obtainable for a particular job, therefore, is the one best to use on that particular job since no one electrode is equally suited to all jobs.

The object of welding is to obtain welded joints equal in strength or stronger than the base metal, i.e., the metal being welded, and the electrodes must be chosen accordingly. Even with the best electrodes and good welding apparatus the welding arc can be manipulated so that the best results will not be obtained. The arc must be held short and the metal deposited in the molten crater must be directed by skillful manipulation, which is acquired only by much repetition and practice.

While the use of a long arc is condemned by many welders, there is danger of using an arc which is too short and which "sputters" considerably. This short arc usually results in the "freezing" or sticking of the electrode to the base metal. The "freezing" or sticking results from the end of the electrode entering the molten pool which extinguishes the arc, thus permitting the molten metal to solidify quickly. All spots caused by too long an arc, by a poor electrode, by a "sputtering" arc, or by "freezing" of the electrode, should be chipped out before proceeding with the weld in order to avoid leaks and hidden flaws.

In general, the metal electrode for welding the commercial grades of wrought iron, steel plates, structural and cast steel, and to some extent cast iron, should be a high grade electrode of low carbon steel wire which has a carbon content of 0.15 per cent or less. Practically all commercial arc welding wire on the market meets this requirement, although there are a number of special electrodes containing greater amounts of carbon which are used for special purposes. The medium and high carbon steel electrodes are used where a hard deposit is required, but are not generally satisfactory where strength is necessary. When ordering electrode material "Electric Welding Wire" should be specified since similar wire for oxy-acetylene welding is often treated in such a way as to render it unsuitable for electric arc welding.

The electrode wire should be cut into pieces convenient for han-

first-class welding materials as electrodes, and not just any

dling in the electrode holder. A length of 14 to 18 in. is satisfactory since it is about the greatest length an operator can handle satisfactorily; at the same time this length is most economical as regards the wastage of stub ends.

It is impossible either to start an arc or to maintain it with an electrode which is red hot. The exact working temperature varies with different electrodes, but in general it is advisable to keep the electrode cool. The heating effect of the welding current passing through the wire, together with the heat conducted back from the arc, tends to heat that portion of the electrode wire carrying current and which extends between the holder and the weld. Therefore, when the welding current is high for the size of wire being used it should be gripped in the middle. Under this procedure the portion of the wire carrying the current can be consumed before it has time to become too hot for use. With lower current values, the electrode may be gripped by the outer end in order to save time and in order to minimize the number of times the arc must be interrupted for the purpose of changing the position of the holder. With some types of fluxed electrodes the flux tends to increase the conductive properties of the electrode so that for ordinary welding the electrode may always be gripped at the end.

The American Welding Society has issued specifications covering the chemical analysis of welding wire to be used for commercial work. These should be consulted when there is any doubt as to the proper wire to be used.

Fluxed and Covered Electrodes and Their Uses.—The use of flux-covered electrodes is not as extensive in America as it is in England. The main use for these electrodes in this country is for welding of non-ferrous metals and the alloy steels. Suitable fluxes tend to increase the stability of the welding arc and by preventing heat radiation increase the rate of melting of the electrode. In some cases the flux is used to introduce some element into the deposited metal which will improve it and which is desired for the purpose to which the weld is to be put.

Wire for Welding Steel.—For ordinary arc welding of commercial grades of mild steel, a mild steel rod or wire is used.

The commercial sizes of electrodes used for general welding are 1/16, 3/32, 5/32, 3/16 and ¼ in. in diameter and 14 to 18 in. long. There are also other sizes for special purposes.

CHAPTER VI

PRELIMINARY PRACTICE WORK

When the welding arc is drawn between the metal to be welded and a metal electrode, the process is called "Metal Arc Welding." When a carbon or graphite rod is used for one terminal of the arc, the process is called "Carbon Arc Welding."

For "metal arc welding" work the electrode is simply a metal

rod or wire, which supplies the filler metal. The arc struck between the metal electrode and the work instantly fuses the end of the electrode and carries this metal to the work, thus forming a solid homogeneous joint. Metal can thus be deposited on vertical surfaces or in any position and the metal arc welding provides by far the best means by which metal can be successfully deposited on overhead work.

In carbon arc welding the additional metal required by the weld is supplied by a "welding rod" which is melted in the arc.

The *metal arc process* requires a comparatively low energy input. The metal deposited has a smoother and more regular appearance than one made by the carbon electrode. For these reasons the metal electrode is very extensively used.

The *carbon arc process* is often used for building up metal, plugging holes in castings, welding and joining parts where appearance is not essential and speed is desirable. Metal can be built on by melting from a welding rod in a manner similar to soldering with an iron or to welding with a gas torch.

Welds soft enough to be machined can be made by either method if reasonable care is taken. The deposited metal should not be chilled, and if the carbon or graphite electrode is used the arc should be long enough to prevent carbon being carried into the weld.

The deposited metal is obviously cast steel, since it is merely fused in place and is not ordinarily subjected to any mechanical working afterward. This metal will, therefore, have the coarse crystalline structure found in unannealed cast steel and likewise will have comparatively low values for reduction of area and elongation when specimens are tested in a tensile testing machine. Annealing by heat treatment or the deposition of subsequent layers of weld metal will of course increase the ductility of the deposited metal.

Preliminary Preparation for Welding.—While learning to weld the beginner will find it convenient to use a bench or table with a steel plate top connected to the ground as described before. The advantages of this table are:

1. The welder can sit in a comfortable position and by avoiding a strained position can better concentrate on the exercise.
2. The steel top will catch many of the sparks and prevent burning the floor or bench.
3. The exercise plates can be laid on the steel top which will make the connection to the ground circuit.
4. For vertical and overhead welding the jigs for holding the plates in proper position can be attached to the bench top by tack welds.

A screen should be placed around the table to protect the eyes of others.

It is recommended that the beginner use a face shield during the exercises on metal arc welding since it keeps the left hand occupied and prevents using the left hand as a brace for the right hand. Also the shield can be quickly moved before the face, al-

For "metal arc welding" work the electrode is simply a metal

lowing the operator to visibly direct the electrode, until the instant before it makes contact, and strikes the arc.

Materials Required.—The materials required for arc welding are as follows:

A source of welding current with suitable means of current adjustment, a hand shield, the necessary cables, and an electrode holder.

1 welding table about 30 in. high with stool and screens.

1 twelve to sixteen-lb. sledge with wedge head for breaking welds.

1 heavy iron or steel block, 1 ft. by 2 ft. 6 in. thick, used as an anvil for breaking welds.

2 small blocks of steel 3 in. by 3 in. by 1 ft.

1 bench vise attached to table.

1 machinist's hammer 1½ to 2 lbs.

Several cold chisels.

1 steel wire scratch brush.

Several pieces of copper ½ in. by 3 in. by 6 in.

A considerable stock, 50 or 75 pieces of sheet steel, about 3 in. by 6 in. by 3/16 in. or 3/8 in. These may be pieces of scrap steel and for the first 12 exercises need not have smooth edges.

A supply of standard welding wire, 5/32 in. diameter cut to length of about 14 in. and reasonably straight; 50 lbs. is enough to start, as this material can be purchased as needed.

The Beginner As an Observer.—The beginner will profit greatly by watching, for a time, an experienced welder. He should closely observe the motions used in striking the arc and in moving along a weld. His ear will become accustomed to the sounds of the arc,

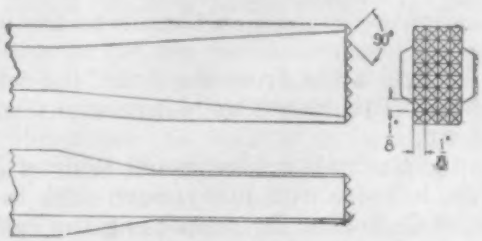


Fig. 18. Roughing tool for removing scale and slag from welds

both when it is too long and when it is of proper length. By using an electrode holder and electrode, but without any current, he can practice the motions of striking the arc. The face shield should be used just as though an arc were to be struck, as the operator should make it a habit to always cover the eyes before striking the arc. Repeated "flashes" of the arc on the eyes, even though they are only momentary, will cause eyeburn.

Position of the Welder.—The welder should sit on a stool directly in front of the work, as shown in Fig. No. 19, with his shoulders

hand. Also the shield can be quickly moved before the face, al-

squarely parallel with the edge of the work table. His feet may rest on the floor, or a foot rail under the table, or on the rungs of the stool or wherever they will be comfortable. This position tends to prevent involuntary movement.

The electrode holder should be held in the right hand, just tightly enough to fully control its movements and not gripped so tightly that the muscles are cramped or bound in any degree. The

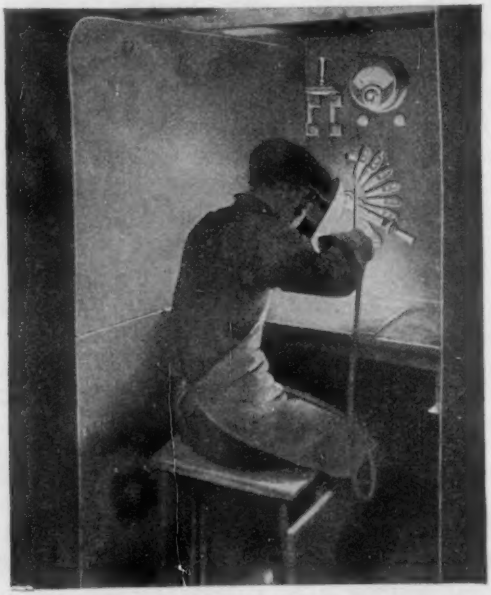


Fig. 19. Correct position of welder, showing shield, electrode, electrode lead, and work table

elbow should be held away from the body, the whole arm being almost horizontal. This leaves the entire arm free to move from the shoulder down.

The cable to the electrode holder should be drawn over the welder's lap from the left side with just enough slack to allow free motion of the electrode holder. By supporting the cable in this way, the weight and drag of the cable is kept off the right hand. Some operators prefer to loop the cable over the right shoulder.

The face shield should be held in the left hand with the elbow braced against either the table or the welder's left knee so as to steady the body. In general, the operator should try to get in any easy position where the whole body is comfortable and braced so as to be steady without strain, leaving the right arm entirely free.

Striking the Arc.—The principal precaution to be observed in striking the arc is to guard against "freezing" or "sticking" the electrode to the work. This freezing or sticking of the electrode occurs when the electrode touches the work only on a small surface, a point or sharp corner. As more of the electrode melts and as it is

being pushed against the plate, the end of the electrode will weld fast. The current then rapidly heats the rest of the electrode unless it is broken away at once. This trouble may be avoided by quickness in making the electrode touch the work and come back just away from the plate. The electrode should be drawn back to the arc length somewhat more slowly than the movement in the first part of the action. The act of "striking" the arc is illustrated in Fig. No. 20. In the effort to prevent sticking, the beginner may have a tendency to jerk the electrode away too rapidly and too far thus "breaking" the arc.

When practicing "striking" the arc, the welder should first adjust the current for about 155 amps. for use with 5/32-in. electrodes.

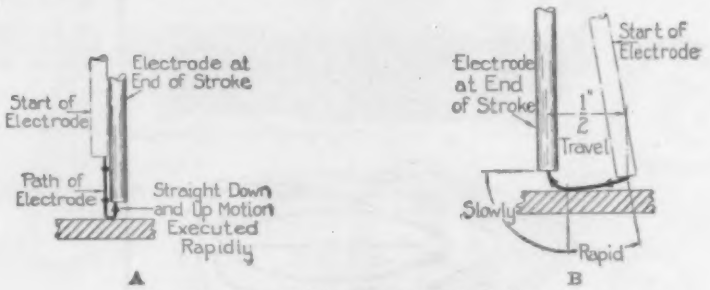


Fig. 20. Two methods of "striking" the arc

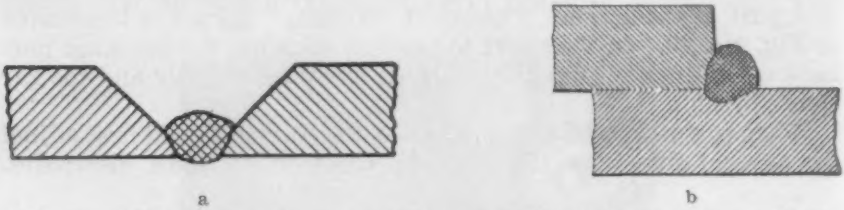
(Instructions accompanying the welding equipment will give directions for this adjustment.) With an ammeter in the circuit it is possible to set the current by holding the electrode holder against the plate and reading the number of amperes. This value will be roughly about one-third more than when the arc is being held. To obtain 155 amperes in the arc, the short circuit current should be about 200 amperes. The operator should now hold the electrode in a vertical position, as shown in Fig. No. 20, and bring it to the point on the plate where the weld is to be started but without touching the plate until the hand shield is moved in front of his face.

He should then touch the electrode very lightly and quickly to the work by a motion of the wrist. This motion is a quick picking action shown by *A* in Fig. No. 20. The movement in touching the plate and just freeing the electrode should be quick. Then more slowly bring the electrode away about 1/8 in. or until the arc has the proper snapping sound. Hold the arc a few seconds and then break it. If the electrode sticks or freezes, immediately bend it from side to side with a steady pull which will probably free it. If this procedure fails and the electrode becomes red hot, the circuit should be opened by one of the following methods:

1. By opening the line switch.
2. By freeing the electrode from the holder, or—
3. By lifting the plate from the bench.

On cooling, the electrode can be broken away with a hammer.

The welder should practice starting the arc in this way, holding the arc a little longer at each attempt and moving it slowly over the plate until he is able to start and hold the arc consistently. He should move the arc straight along and not try to



a b

Fig. 21. Overlap and penetration studies. (a) Section indicates proper selection of welding current and electrode diameter to secure fusion. (b) Adequate fusion obtained by increasing arc terminal energy to compensate for increased rate of heat flow

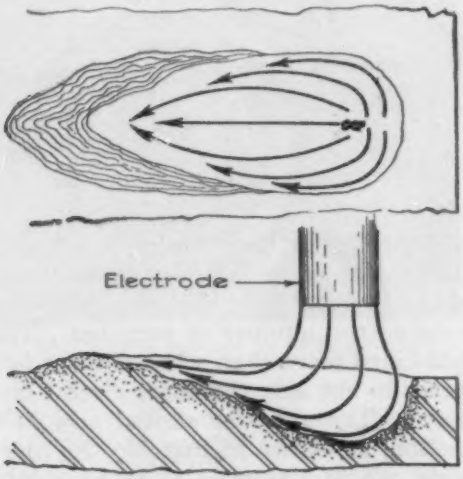


Fig. 22. Diagram showing flow of weld metal when welding

spread the bead or to weave or impart a zig-zag motion to the electrode holder.

A method of striking the arc to avoid "sticking" is shown in *B* of Fig. No. 20. In this method the action to a certain extent consists of scratching the electrode on the surface of the plate. The withdrawal of the electrode should be slower than the rest of the motion.

Depositing Metal.—In advancing the arc, care should be taken not to move the electrode faster than it is possible for the arc to melt a place on the plate for receiving the deposited metal. If the arc is moved too rapidly the metal will be merely laid on the plate with no penetration. The operator should keep the arc traveling forward just fast enough to keep it at the forward edge of the

crater. This is the greatest speed of travel possible with the combination of plate thickness, electrode diameter and current used. Traveling the arc forward less rapidly will result in a bead somewhat higher and wider. Too slow a speed will result in an overlap of the bead and possibly in oxidized metal caused by the melting of a large crater and an exposure of this hot metal to the air. The gases and vapors from the arc will to a certain extent protect the metal in a small crater.

These exercises should be continued by the operator until he is able to start the arc practically every time. Gradually increase

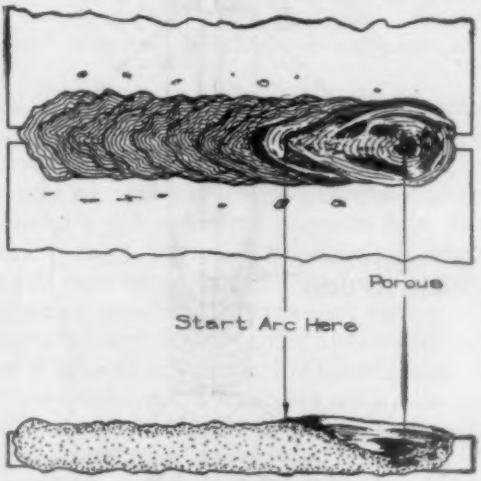


Fig. 23. Section of deposited metal showing penetration and crater

the length of the bead and make curved lines and letters, but do not weave.

The operator should now begin to examine the beads deposited while moving the arc along the plate, by comparing them with Figs. 15 and 23. The sound of the arc, and the appearance both from the standpoint of length and size and also the size and number of sparks should be noted in connection with the appearance of a bead. Chip off the bead, commencing at the end where the weld was begun since this is usually the weakest point. Continue making beads 3 or 4 in. long until the bead has the appearance of a good weld, that is, even height, width, no overlap, good penetration. If a voltmeter is connected to measure the arc voltage, it will help to have someone observe its readings and advise from time to time what the voltage is. It should be kept from 16 to 18 and the appearance under these conditions noted.

The operator should now repeat the exercise, first using a current of 100 amperes in the arc and then of 75 or 80. These operations will require increasingly greater steadiness of the hand both in starting and in holding the arc after it is started. The observa-

tions as to arc sound and appearance should be checked in each case against the appearance of the bead. The surface of the bead should consist of regularly spaced ripples with no holes or spongy places. No large drops of metal should be deposited outside the weld on the plate and when the bead is chipped off it should be necessary to cut it away the full width of the bead, thus showing that there is no overlap.

It will be noted that wherever the arc stops there is a spongy, porous spot in the crater. In the case of long welds where it is

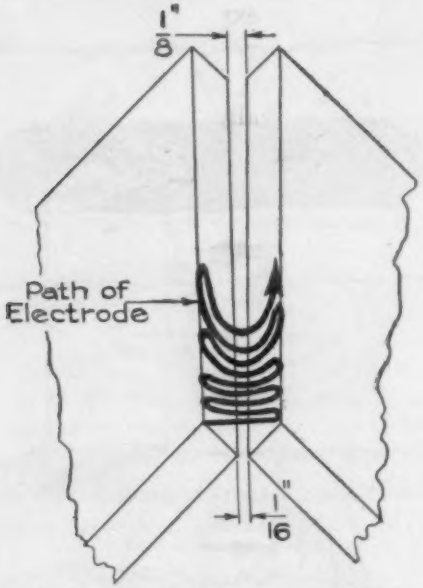


Fig. 24. Path of electrode in making right angle joint in flat position

necessary to use more than one electrode, such a spot will be found wherever the arc is stopped to change electrodes. In recommencing such a weld, the arc should be started just at the rear of the crater (See Fig. No. 23) and the weld carried across it.

It can now be assumed that the welder is able to start an arc and hold it uniformly for a short time. From this point on the exercises will take the form of progressively difficult type jobs with certain objectives specified and certain requirements which are to be met by the finished weld before the student should pass on to the next type job.

General Instructions.—In approaching each new type job the student should consciously divide the preparation into several distinct steps. These steps are indicated in the following table:

Steps to Be Performed	*Reasons or Points to Be Emphasized*
1. Place work plate on bench.	1. Bench should be clean so work will be steady, and make good electrical contact with the ground lead.
2. Clean metal where weld is to be made.	2. See p. 16 of text as to impurities.
3. Make ground connection.	3. If necessary, the plate should be cleaned with a scratch brush or chisel to provide a good electrical contact and to avoid local heating and waste of power at this point.
4. Put electrode in holder.	4. Electrode may be gripped at the middle if the work requires very steady handling of the electrode. Holding the electrode by the end makes it unnecessary to stop the arc to change the electrode but makes it more difficult to hold the arc steady.
5. Adjust the current.	5. The value of current to be used for each exercise is given in the instructions. The method to be used in adjusting for current depends on the type of welding equipment and such instructions are usually supplied with the equipment.
6. Strike the arc and make the weld.	6. The details of this step will depend on the requirements of the problem.

Exercise Jobs.—The suggested type welding jobs given on the accompanying analysis were selected as being most suitable for preliminary practice work. The apprentice welder should perform satisfactorily as many of these exercises as in the judgment of the instructor are necessary to prepare him for placement on production work. As rapidly as possible all apprentices should be placed on real jobs where their efforts and energy will be expended in producing welds of permanent value. Numerous type jobs of this character are listed in the succeeding chapters.

The apprentice should also seek all functioning information, to which reference is made in the analyses under the headings of auxiliary information, trade science, drawing and mathematics.

These type welding jobs are given on pages 42 to 46. The student welder should, however, first study very carefully the illustrated methods of welding various forms of joints shown in Figs. 25 to 31 and later on the joints illustrated in Figs. 32 to 36.

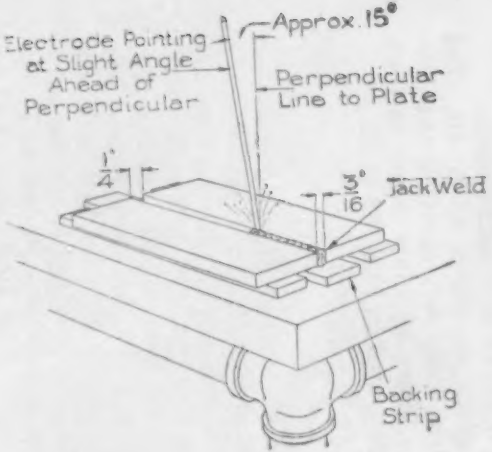


Fig. 25. Method of making an open butt weld

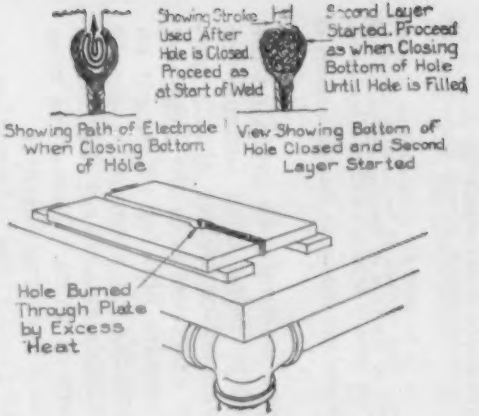

Showing Stroke Used After Hole is Closed. Proceed as at Start of Weld
Second Layer Started. Proceed as when Closing Bottom of Hole Until Hole is Filled
Showing Path of Electrode when Closing Bottom of Hole
View Showing Bottom of Hole Closed and Second Layer Started
Hole Burned Through Plate by Excess Heat

Fig. 26. Method of filling hole in butt weld caused by arc melting through

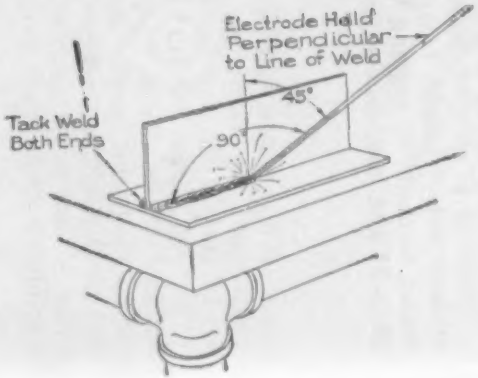


Fig. 27. Method of making single fillet in a T joint

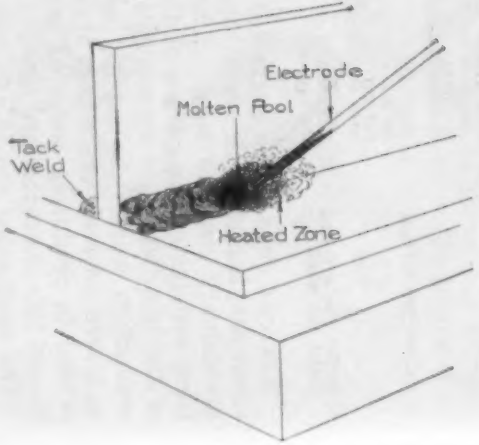


Fig. 28. Diagram showing heat distribution in T joint

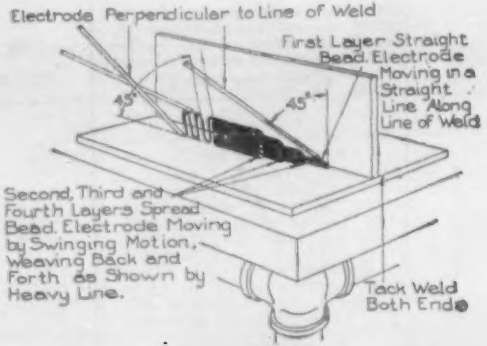

Electrode Perpendicular to Line of Weld
First Layer Straight Bead. Electrode Moving in a Straight Line Along Line of Weld
45°
45°
Second, Third and Fourth Layers Spread Bead. Electrode Moving by Swinging Motion, Weaving Back and Forth as Shown by Heavy Line.
Tack Weld Both Ends

Fig. 29. Method of making a four layer fillet weld in flat position to form a T joint

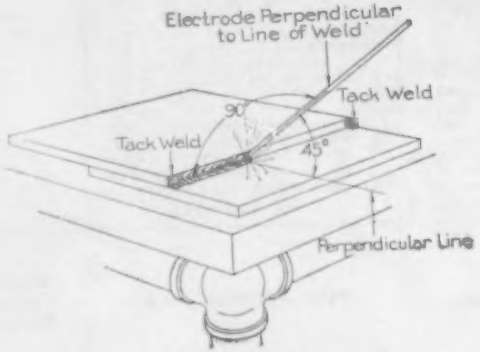


Fig. 30. Method of making fillet weld in flat position on edge of lap joint

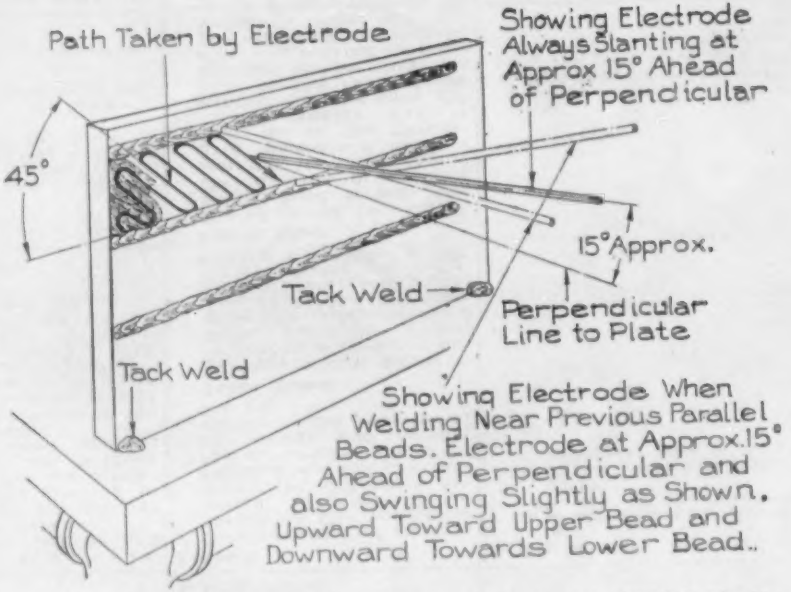

Path Taken by Electrode
Showing Electrode Always Slanting at Approx 15° Ahead of Perpendicular
45°
15° Approx.
Tack Weld
Perpendicular Line to Plate
Tack Weld
Showing Electrode When Welding Near Previous Parallel Beads. Electrode at Approx. 15° Ahead of Perpendicular and also Swinging Slightly as Shown. Upward Toward Upper Bead and Downward Towards Lower Bead.

Fig. 31. Method of filling in between parallel horizontal spread beads on vertical plate

ANALYSIS OF PRELIMINARY PRACTICE WORK WITH THE METAL ARC

Checking Level Number	Type Welding Jobs	Objective for Checking Level	Auxiliary Information 1. Knowledge of stock a. Recognition b. Working properties. 2. Use and care of tools. 3. Safety First. 4. Preparation.	Science Drawing Mathematics
1	**Type Job No. 1** Striking and breaking the arc on a piece of ⅜ or ½" scrap plate, using ⅛ or 5/32" bare low carbon iron or steel electrodes.	1. To properly grip the electrode in the holder and ground the work. 2. To strike the arc without the electrode sticking to the work and the breaking of the arc without causing a deep, spongy, oxydized crater. 3. To develop freedom in the use of the welding arm so as not to depend upon any rigid or body support. 4. To keep the bench or slab clean, so that the exercise plate will lay flat and have a perfect ground.	1. **Stock** No recognition of stock is needed at this beginning period. Student should know the difference between direct and alternating current and the effect of voltage and current values on the behavior of the arc. **Trade Terms** Voltage, current, amperes, voltmeter, ammeter, electrode, electrode holder, generator lead, welding lead, electrode holder lead, electrode receptacle, transformer, motor generator, welding slab, short circuit. **Safety First** Use of gloves, face shield, helmet hood, screens, and the wearing of suitable clothing. Instructor should give elementary instructions as to the occupational dangers due to exposure of the eyes and skin to the rays of the arc, and the necessary instruction bearing upon the protection of neighboring workmen.	1. Preliminary information on: 1. Generation and distribution of the electric current. 2. Transformer and motor generator sets.
2	**Type Job No. 2** Deposit beads in the flat position on a piece of ⅜ or ½" scrap plate, using ⅛ or 5/32" bare low carbon iron or	1. To have work clean and free from grease, rust and scale.	Instructor should inform the student by illustrations and examples as to the different kinds of metal that are ordinarily	The arc is approximately 4 to 6 times as hot as the melting point of steel. Electrical and heat conductivity of different metals,

2 (Cont'd)	steel electrodes. Beads should be started on edge of plate remote from the operator and deposited towards the operator. Beads should be about ¾" apart.		welded by the arc. He should instruct him how to read the ammeter and voltmeter, how to regulate the welding set and the methods of protecting the welding leads and the care of equipment.	e.g., steel, copper and cast iron, vary considerably.
3	**Type Job No. 3** Running adjacent, parallel beads in the flat position on a piece ⅜ or ½" scrap plate, using ⅛ or 5/32" bare low carbon iron or steel electrodes. Beads should be started on edge of plate remote from the operator and deposited towards the operator.	To obtain: 1. Fusion of each bead with plate and to adjacent bead. 2. Uniformity of bead in both height and width. 3. A deposit of clean metal by the use of a wire brush.	Instructor should explain why the plate warps when the deposited metal has cooled.	Both the base metal and the previously deposited metal must be melted to make a weld.
4	**Type Job No. 4** Building up a pad of metal 3"x6"x1" in height in the flat position on a piece of ¾" or ½" scrap plate, using ⅛ or 5/32" bare iron or low carbon steel electrodes. Beads of each layer should be deposited at right angles to beads of previous layer, and should be commenced at edge of plate remote from the operator, plate being turned on completion of each layer.		**Instructor should explain** 1. Effect of layer direction on tensile strength and ductility of deposit. 2. Annealing effect of each layer on previously deposited layer or layers.	

ANALYSIS OF PRELIMINARY PRACTICE WORK WITH THE METAL ARC—Continued

Checking Level Number	Type Welding Jobs	Objective for Checking Level	Auxiliary Information 1. Knowledge of stock a. Recognition b. Working properties 2. Use and care of tools. 3. Safety First. 4. Preparation.	Science Drawing Mathematics
5	**Type Job No. 5** Same as Type Jobs Nos. 2, 3 and 4, except that plate surface is in the vertical position, and in Type Jobs Nos. 2 and 3, beads are deposited upwards. In type Job No. 4 the plate is not turned, alternate layers being deposited upwards and from left to right. Beads deposited from left to right should start at the bottom of the deposit.	To develop ability of student to deposit metal on vertical surfaces.	Instructor should call attention to: 1. The necessity of preferably depositing the metal upwards so as to make a deposit which is free from slag and oxide inclusions. 2. The necessity of having electrode at a suitable angle and using a correct current value.	
6	**Type Job No. 6** Same as Type Jobs Nos. 2, 3 and 4, except that plate surface is in the overhead position.	To develop ability of student to deposit metal on overhead surfaces.	The instructor should explain the necessity of using a short arc, a suitable current value and how the student should protect himself from falling metal.	The theory of metal transfer in the arc and surface tension.
7	**Type Job No. 7** Outside corner weld made in flat position and formed by the straight edges of two 3/8" or 1/2"x3"x6" steel plates, placed at right angles along the 6" edge. Joint should be tacked at each end before starting to weld, with bottom edges 1/4" apart. Weld should be made in two continuous layers with 5/32" bare low carbon iron or steel electrodes, without a backing strip, and metal deposited toward the operator.	To develop ability of student to: 1. Weld two plates together. 2. Move electrode tip so as to prevent slag inclusions in the weld and to secure fusion on both edges of the plate forming the weld. 3. To secure a uniform bead at the bottom of the weld.	The instructor should call attention to the importance of securing uniform penetration at the bottom of the weld and see that enough metal is deposited in the weld. He should explain why high residual stresses will not be found in this form of joint. He should have student fracture all his welds to observe their soundness and progress made.	1. Residual stresses. 2. Various forms of weld and types of joint.

8	**Type Job No. 8** Same as Type Job No. 7 except that weld is made in the vertical position and the metal deposited upwards.	To develop ability of student to make a vertical weld.	Instructor should have student fracture all his welds to observe their soundness and progress being made.	
9	**Type Job No. 9** Same as Type Job No. 7 except that weld is made in the horizontal position. Weld should be started at the left hand end of the joint.	To develop ability of student to make a horizontal weld.	Instructor should explain the necessity of moving the electrode tip so as to deposit metal in the weld with the natural contour produced by the influence of gravity. He should have student fracture all of his welds and observe their soundness and progress being made.	
10	**Type Job No. 10** Same as Type Job No. 7 except that weld is made in the overhead position.	To develop ability of student to make an overhead weld.	Instructor should have student fracture all of his welds to observe their soundness and progress being made.	
11	**Type Job No. 11** 60 degree single Vee butt weld in the flat position and formed by two ⅜" or ½"x3"x6" steel plates with a 30 degree bevel along the 6" edge. Joint should be tacked at each end before starting to weld, with bottom edges ⅛" apart. Weld made in two layers with $\frac{5}{32}$" bare low carbon electrodes, metal being deposited toward the operator.	To develop ability of student to: 1. Make a weld of single Vee butt form without melting away too much of the thin edges at the bottom of the weld. 2. To secure a uniform bead at the bottom of the bevel.	The instructor should explain the method of depositing metal by the step-back and intermittent methods and the advantages of each. He may have student make welds 2 to 4 feet long, using these methods. Instructor should have student fracture all of his welds to observe their soundness and progress being made.	
12	**Type Job No. 12** Same as Type Job No. 11 except weld is made in one layer.	To develop ability of student to handle a greater amount of molten metal in the weld without entrapping slag and oxide.	Instructor should stress the importance of correct movement of electrode tip and should have student fracture each weld made.	

ANALYSIS OF PRELIMINARY PRACTICE WORK WITH THE METAL ARC—Continued

Checking Level Number	Type Welding Jobs	Objective for Checking Level	Auxiliary Information 1. Knowledge of stock a. Recognition. b. Working properties. 2. Use and care of tools. 3. Safety First. 4. Preparation.	Science Drawing Mathematics
13	**Type Job No 13** Same as Type Job No. 12 except that joint is tacked at one end only, the other end being spread approximately 3/8" apart so as to form the semi-rigid type of joint.	To weld a semi-rigid type of joint and on completion of weld have joint edges parallel.	Instructor should explain why one layer is necessary in this type of joint, how to calculate the necessary angular divergence of joint and the mechanical methods used for keeping joint edges apart during welding.	Location and nature of residual stresses in the joint due to the expansion and contraction of the base and weld metals. Angle of divergence of joint edges approximately 1½% of length for ingot iron and steel.
14	**Type Job No. 14** Beads run on a piece of scrap plate with bare low carbon iron or steel electrodes varying in size from 1/8" to 3/8" in diameter.	To develop ability of student to handle electrodes of varying diameters and to become acquainted with correct current values for each size and the relative suitability of each size for welding metal of various thicknesses.	Instructor should impress on the student the commercial necessity of depositing the maximum amount of metal per hour in order to successfully compete against riveting and thus advance the art of welding. To do this the student should aim to use largest electrode and the highest current value suitable for each job, even if it is necessary to cool the electrode holder in water or alternately use two electrode holders. Instructor may also have student weld some double-Vee butt and lap joints in 3/8" or 1/2" plate.	As large an electrode cannot be used for vertical and overhead welding as can be used for flat welding. Two independent drops of water will remain suspended from the ceiling but should they coalesce and become one they drop off.
15	**Type Job No. 15** Beads run on a piece of 3/8" or 1/2" scrap plate with coated and covered low carbon iron or steel electrodes varying in diameter from 1/8" to 3/8".	1. To acquaint student with various forms of metal electrodes and their uses. 2. To acquire the special technique peculiar to each form of electrode.	How coatings and coverings are applied to electrode and their composition. Instructor may also have student weld some double-Vee butt and lap joint in 3/8" or 1/2" plate.	

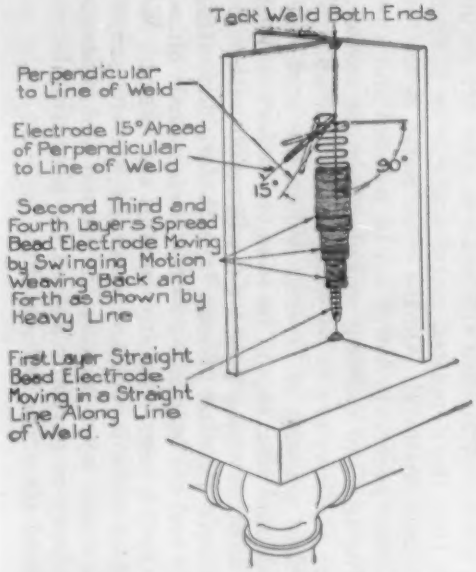

Tack Weld Both Ends
Perpendicular to Line of Weld
Electrode 15° Ahead of Perpendicular to Line of Weld
15°
90°
Second Third and Fourth Layers Spread Bead Electrode Moving by Swinging Motion Weaving Back and Forth as Shown by Heavy Line
First Layer Straight Bead Electrode Moving in a Straight Line Along Line of Weld

Fig. 32. Method of making a four layer T weld in a vertical position

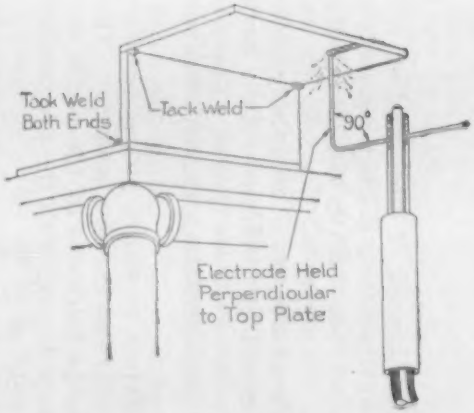


Fig. 33. Illustration of overhead welding

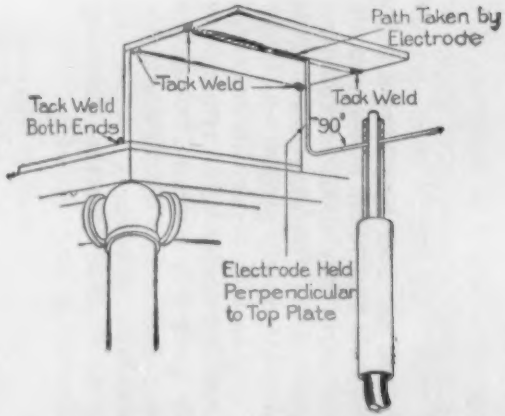


Fig 34. Method of making an overhead straight butt weld

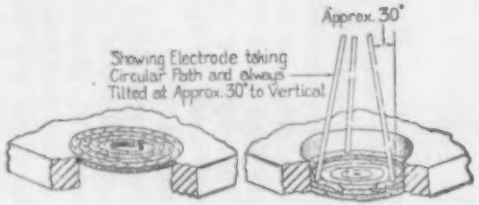


Fig. 35. Method of filling holes in a horizontal plate

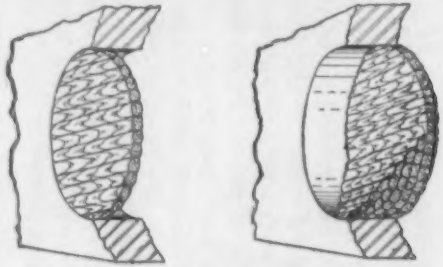


Fig. 36. Method of filling holes in a vertical plate

CHAPTER VII

WELDING STEEL WITH METAL ARC

In order that the student welder and engineer may have a thorough understanding of the fundamentals that enter in the making of good welds in the joining of steel parts they should at this time review carefully the previous chapter on the "Welding Arc." This chapter covers fundamental considerations as, proper manipulation and maintenance of a short arc, correct deposition of metal and proper penetration. Unless the principles set forth in this chapter are carefully followed, poor work will result. The readers should also study the forms of joints shown in Figs. 8, 9 and 10, as they are particularly applicable to welding of steel.

The Arc Welding of Steel may be divided into the following classes:

1. Low carbon steel.
2. High carbon steel.
3. Alloy steels.

Low Carbon Steel.—The greatest amount of steel welding will fall in the class of low carbon steel, therefore, it will be given the most consideration. This will include the welding of plates, structural shapes and forgings.

In welding low carbon steel if direct current is used the positive (plus) lead from the generator should be connected to the work and the negative (minus) lead to the electrode holder. There is no difference in the leads from the alternating current welding equipment.

The current used should be sufficient to secure proper penetration and fusion of the deposited metal and the base material. This current will, therefore, vary with the thickness of the plates and size of the electrode, and, in a lesser degree, with the preparation of the edges and the position of welding.

If too high a current is used the weld will be brittle and there is also danger that the deposited metal will not be properly combined with the base material. On the other hand, if too low a current is used proper penetration will not be secured and a poor weld will result. The speed of welding will also be much slower.

Where heavy sections are to be welded it is desirable to deposit the weld metal in a series of layers. When the first layer is deposited all scale and slag should be removed before depositing the second layer; as otherwise a poor weld will result with many undesirable inclusions. Peening of each layer before depositing a new one with an air tool not only removes the surface scale but stretches the deposited metal, removing any cooling shrinkage. Welds deposited in two or more layers are generally better than those deposited with a single layer because the second and subsequent layers have a tendency to partially anneal the preceding layers and a joint of improved structure will result.

Preparation of Edges.—Plates of 3/16 in. or more which are to be joined by metal arc welding should have their edges scarfed to form a single V butt joint such as shown in Fig. 37. For plates of 3/8 in. or more the edges may be scarfed to form either a single V or a double V, such as shown in Fig. 37. If a single V joint is formed the edges of the plate should not be scarfed to a knife edge but a shoulder of a 1/16-in. should be left, such as shown in Fig. 37. The average welder will obtain the best results with a double V weld.

Separation of Plates.—Parts which are to be joined by arc welding should be separated slightly in order that the welder may be able to penetrate to the bottom of the V and obtain good fusion at this point. In general, the table given below should be followed in determining the distance that these plates should be separated.

Table showing opening between the edges of butt joints in inches.

Thickness of Plate	Openings
1/32 to 1/16	0
Above 1/16 to 1/8	0 to 1/32
Above 1/8 to 1/4	1/32 to 1/8
Above 1/4	1/8 to 3/16

Current and Size of Electrode.—It is only possible to give a general statement in regard to the proper current to be used for certain electrode diameters and plate thicknesses in welding steel. The table given below shows the range that should be used for good work where the welding is to be done in a flat or downward position. For welds made either in vertical or overhead positions the lower limits of current shown in the table should be used.

Electrode Diameter	Amperes	Plate Thickness
1/8"	100–160	1/8 to 1/4
5/32"	140–180	1/4 up
3/16"	175–225	3/8 up
1/4"	200–280	3/8 up

Single V joints made in 1/4-in. and 3/8-in. plate should be welded in one layer, 1/2- and 5/8-in. plate in two layers, and 3/4-in. and 1-in. plate in three layers.

In the double V joints up to 1/2-in. plate should be welded in one layer on each side, 5/8—1-in. plate two layers on each side.

It is advisable where 100 per cent strength is desired to reinforce all the single V joints about 20 per cent of the plate thickness. The double V joints should be reinforced about 15 per cent of the plate thickness on each side.

Fillet Welds.—Where a plate is welded to the face of another plate the welding should be done along each edge of the joint. In this case the metal should be deposited to form an angle of 45 deg., as shown in Fig. 8. Here also 1/4-in. and 3/8-in. plate are welded in one layer, while 1/2-in. and 5/8-in. in two layers and 3/4-in. and 1-in. in three layers.

High Carbon Steel.—High carbon steel welding is done in most cases to build up wearing surfaces. The electrode wire usually

ers have a tendency to partially anneal the preceding layers and a joint of improved structure will result.

contains about 1 per cent or more of carbon. In using this type of electrode with direct current the work is connected to the negative lead and the electrode to the positive (reversed polarity). The best results will no doubt be obtained if the wire has a flux coating.

The figures on the accompanying pages illustrate a few of the typical applications made in welding steel parts.

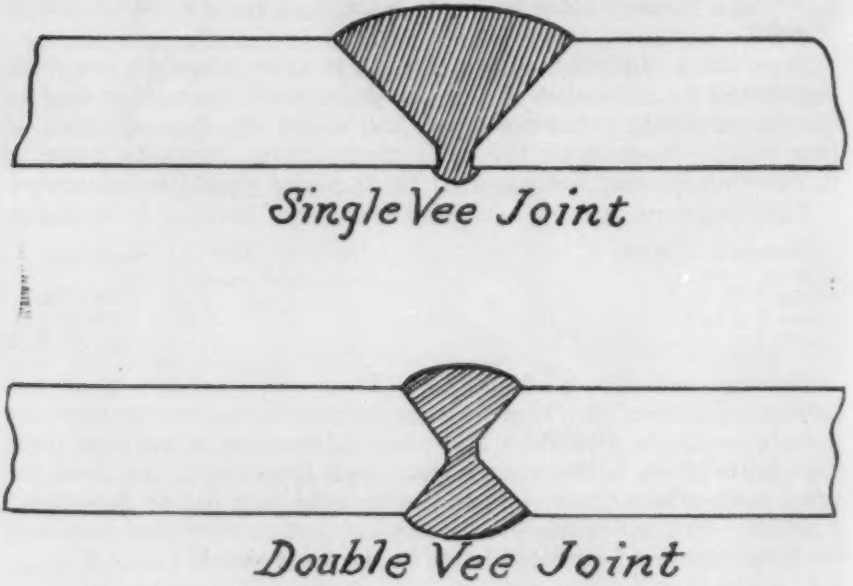


Fig. 37. Proper preparation for single Vee and double Vee welds

Qualifications for Good Welders.—In order that a welding operator may test his skill, test specimens may be prepared in accordance with Bulletin No. 1 of the American Welding Society. If ordinary mild steel is used such as usually found in plate work and structural shapes an average of three tensile samples should not test less than 45,000 lb. per square inch when the weld metal is ground flush with the base metal. The lowest of any one of the three specimens should not be less than 40,000 lb. per square inch.

cases to build up wearing surfaces. The electrode wire usually

REPLACING CASTINGS BY WELDED STEEL PARTS

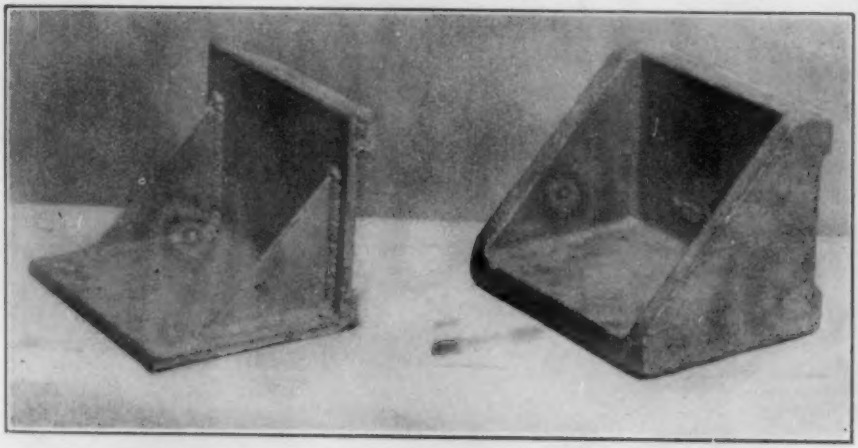


Fig. 38. At left, support made from welded steel parts; at right, casting

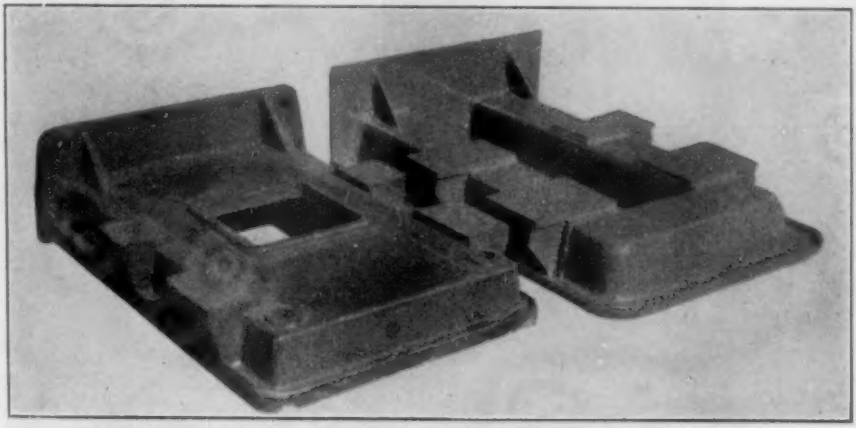


Fig. 39. Elevator base. At left, casting; at right, welded steel base

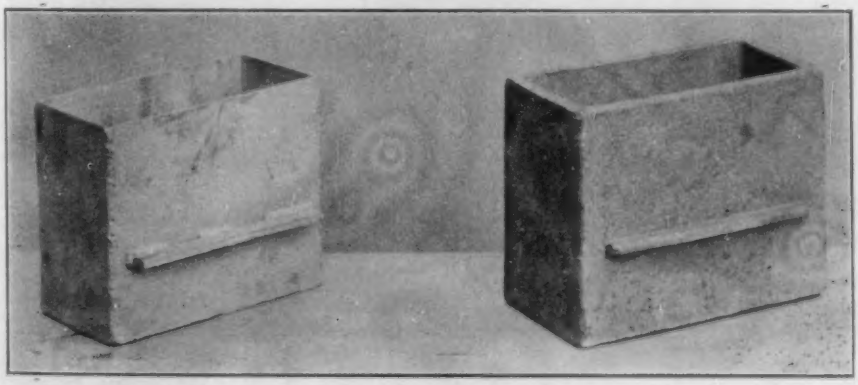


Fig. 40. Wall box. At left, welded steel box; at right, casting

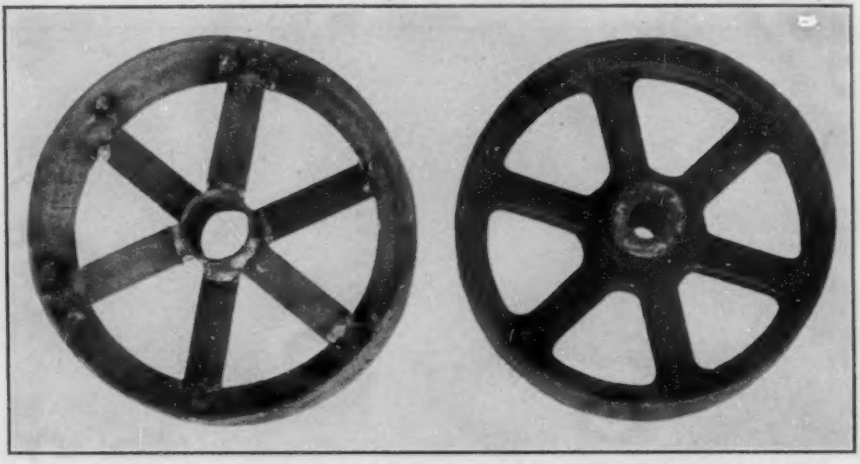


Fig. 41. Wheel for shop truck. At left, welded steel; at right, casting

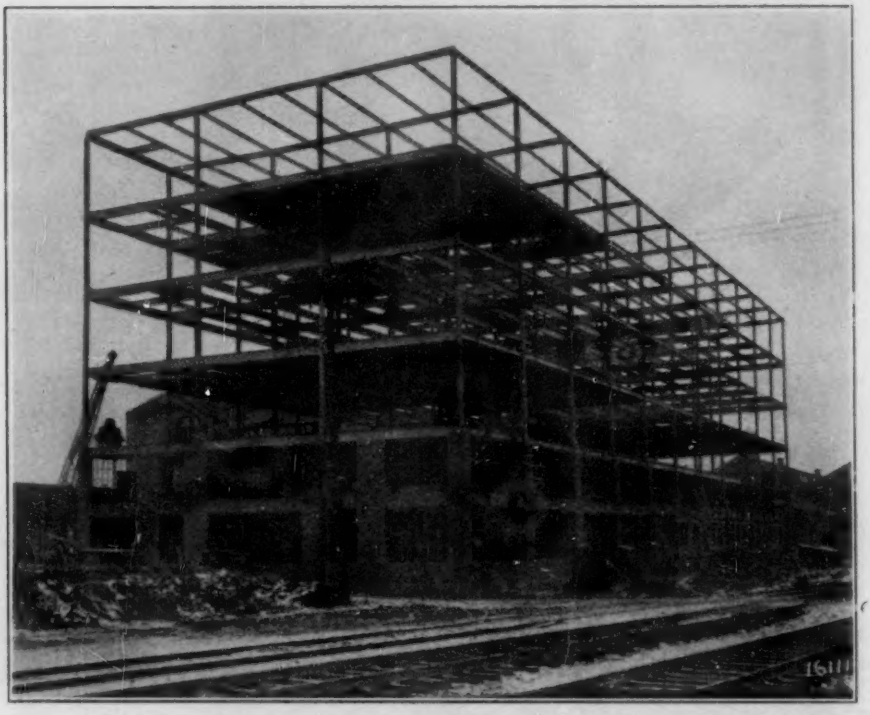


Fig. 42. Five story heavy duty warehouse building at Sharon, Pa., entirely fabricated by arc welding. The welding of structural steel offers enormous possibilities, but requires among other things, proper design, skilled operators and proper supervision

Fig. 40. Wall box. At left, welded steel box; at right, casting

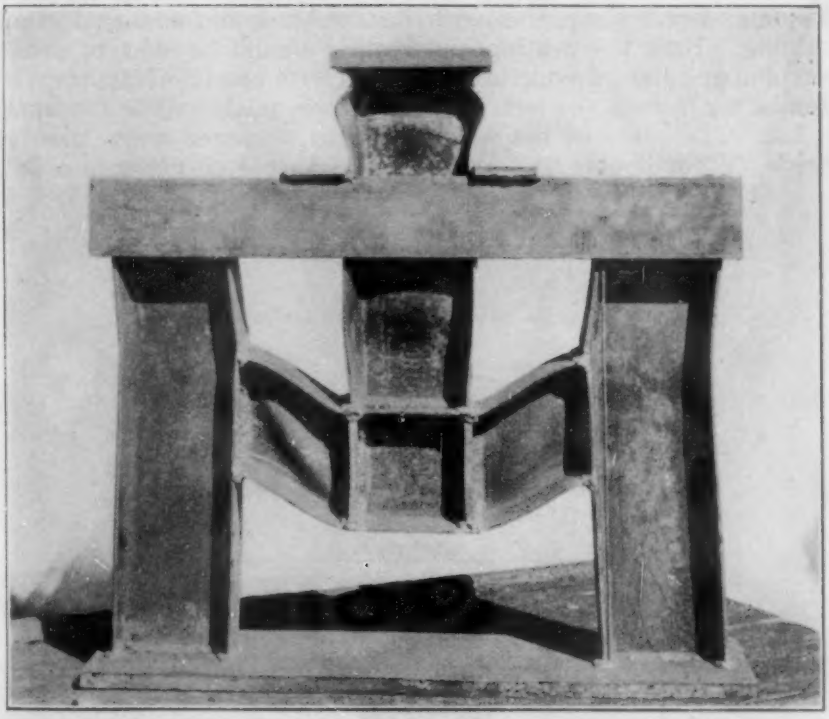


Fig. 43. Welded test specimen having undergone severe shock test. This illustrates that welding is entirely feasible in the fabrication of structures subjected to shock, providing the welding is properly done. Note the deformation of the members

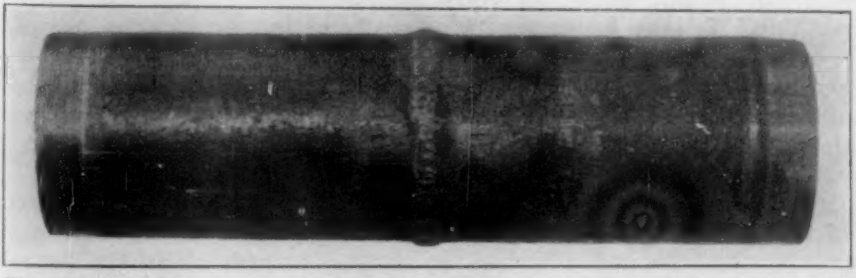


Fig. 44. Welded pipes are now a common occurrence. This application requires skilled and conscientious workmen

CHAPTER VIII

WELDING CAST IRON

Welding Cast Iron Using a Carbon Electrode.—Iron castings should generally be preheated before welding and annealed after welding. Both the heating and cooling should be slow to avoid warping and the introduction of strains with possible fracture. If preheating is used, the weld should be made quickly while the work is hot. The edges of the weld should be prepared with either a single "V" or double "V" and the weld should be made in a flat

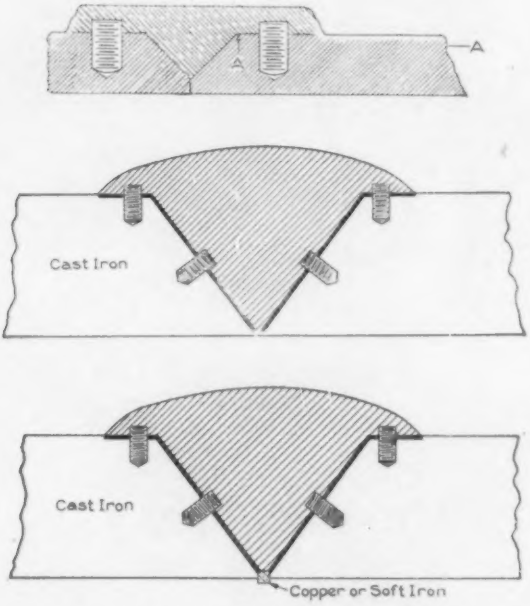


Fig. 45. Cross sections of studded joints, showing use on thin and thick materials and the use of a copper or soft iron strip at bottom of Vee

position. It may be necessary to back up the weld. The use of a suitable flux is recommended although in some cases no flux is necessary. A good flux can be made of a mixture of equal parts of carbonate of soda and bicarbonate of soda. Washing soda is the name commonly given to a somewhat impure carbonate of soda, while bicarbonate of soda is ordinary baking soda. It is not necessary that either should be in a chemically pure state. The action of the carbonates is to combine with the oxygen in the slag, releasing the iron and allowing the oxygen to pass off in the form of carbon monoxide or carbon dioxide. It will be noticed that when a little flux is added to the molten iron under the arc, the surface of the metal becomes clear and mirror-like showing that the impurities have been "fluxed" out.

When welding cast iron with a carbon arc the welder should direct the arc on the upper edges of the groove until they commence to melt and then melt down the bottom of the weld, adding a little flux. As this metal flows together gradually he should first bring the molten metal from the sides down into the groove and then add

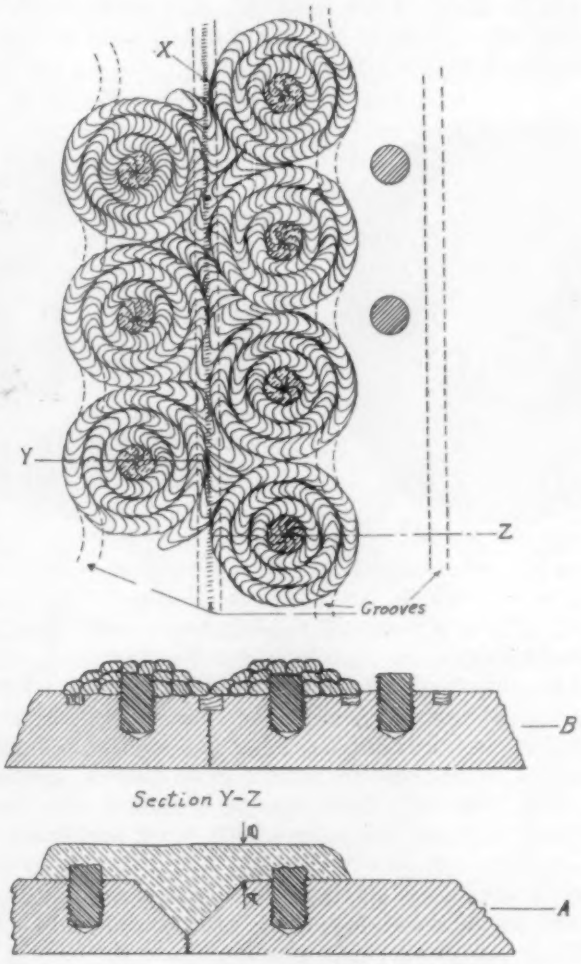


Fig. 46. General procedure recommended for the arc welding on cast iron parts with the metal arc

metal from the filler rod until the metal of the weld is built up as high as desired. The next step is to advance along the weld and repeat this procedure. Care should be taken not to add too much metal at one time nor in any other way permit metal to flow down the groove before the bottom has been melted down and the two edges joined. If metal merely runs down in this way, it will bridge over and cause a "cold shut."

Welding Rod.—The welding rod should preferably be a rod or stick of cast iron but in some cases steel may be used. Special cast iron rods high in silicon and low in manganese are found to be very good. Diameters of ¼ in. for small work and ½ in. for heavy work have been found satisfactory.

Current.—The proper current to be used is determined for each job by the experience of the welder. A maximum of 350 to 400 amperes is seldom exceeded since too much heat causes the metal to run too fast to be controlled.

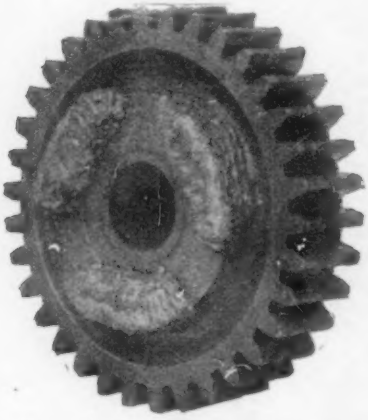


Fig. 47. New bosses built on cast iron drive gear (before machining)

Fig. 48. New bosses built on cast iron drive gear (after machining)

Welding Cast Iron Using a Metal Electrode.—Preheating and annealing are beneficial in connection with cast iron welding but in many cases are dispensed with, due to the size of the casting making such treatment expensive or impossible. Sometimes the electrode is the same as that used for the welding of steel. With this electrode it is difficult to obtain good fusion, particularly on gray iron. Poor fusion is further aggravated by the formation of the "hard zone" around the weld which is an additional source of weakness.

The effect of shrinkage of the metal in the weld as it cools is to draw the two edges closer together. If the shape of the work is such that it cannot give, this shrinkage introduces strains in the work that must be counteracted. Generally a weld will fail in the cast iron just outside the weld. This is the hard zone previously described. If the weld is sufficiently reinforced, the shrinkage or contraction may cause a failure at some other point. Another consideration is the fact that the steel used in the electrode will contract about 50 per cent more than cast iron in cooling from the molten condition. This causes the deposited metal to tend to slip along the cast iron and sets up local strains with possible failure along the surface between these two metals.

The above conditions have to do with the strength of the weld

but should be considered also from the standpoint of machinability, as many castings have to be machined after welding. The "hard zone" will either break a tool or cause it to jump and therefore must be eliminated if the weld is to be machined. Any of the welds may be ground if such a finish is satisfactory.

Qualities Desired in a Cast Iron Weld.—The qualities desired in any given weld are determined by the service to which it will be subjected and will consist of one or more of the three general qualities: (1) strength, (2) machinability, and (3) tightness.

Strength in a cast iron weld may be increased (1) by preheating and annealing, (2) by eliminating the "hard zone" about the weld, and (3) by eliminating strains due to contraction of the heated metal near the weld. These strains if remaining in the casting may be such as to add directly to the strains set up by the normal service and bring the total to a value beyond the strength of the casting.

Studding.—A cast iron weld may be strengthened by anchoring the deposited metal to the casting. Steel studs ¼ in. or larger in diameter should be screwed into holes drilled and tapped into the iron to a depth approximately equivalent to the diameter of the studs and located so that they will be covered by the added metal when the weld is completed. Fig. No. 45 shows a cross section of metal with studs in place. The area of the steel studs should total from ¼ to 1/3 the total area of the weld and in this case the strength of the weld can be taken as the strength of the studs. This ratio corresponds to the ratio between the strength of the cast iron and the strength of the steel, so that such a weld will develop the full strength of the cast iron section. The studs should project ⅛ to ¼ in. above the surface. A square groove chiseled along the sides of the weld has been recommended as a means of anchoring the weld so that the contraction of the added metal in drawing the edges together will be independent of the adhesion between the two metals.

In general, the welding of cast iron with the metal electrode differs in procedure from the welding of steel. In welding cast iron a layer of metal is first deposited over the surface of the cast iron by laying a succession of beads side by side until the surface of the iron is entirely covered. This procedure is followed whether studs are used or not. After the surface is covered with this layer of steel, the weld is made from one side to another just as though the casting were of steel. When studs are used care should be taken to thoroughly fuse the studs into the deposited metal.

Strength and tightness in a cast iron weld may be obtained by lightly peening the deposit with a hammer when changing electrodes. This peening stretches the cooling metal and relieves internal stresses which always exist due to contraction in the deposited metal. Careful annealing will usually relieve these stresses and also prevent brittleness, which generally causes a week weld. In most cases a cast iron weld properly annealed will be

stronger than the original base metal was before annealing. In general, the strength of the weld may be made equal to the strength of the cast iron unless there are some limitations imposed on the method of making the weld.

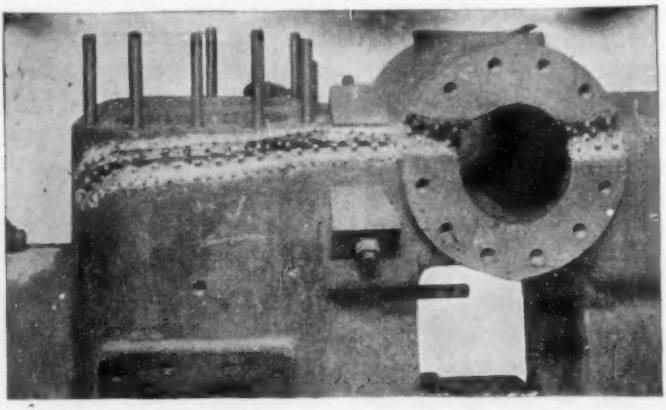


Fig. 49. Cast iron casting prepared for metal arc welding. Note scarfing of edges and placing of studs

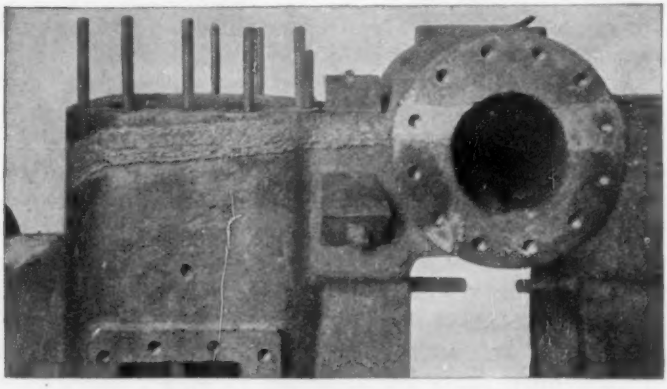


Fig. 50. Cast iron job repaired by welding

A weld may be made machinable by proper annealing. In many cases the use of a copper or soft iron strip, as shown in Fig. No. 45, has been used when one side only of the weld is to be machined, and annealing for this purpose can not be resorted to. In many cases where machinability and tightness are of prime importance special alloy electrodes are used.

Nickel wire and high nickel alloys like monel metal are used extensively in welding a surface where a machinable deposit is desired. This process is of particular importance in the welding of cast iron "cold," that is, without preheating. The nickel appears to prevent the graphite in the cast iron from going into a solution and thus forming the hardened weaker layer of cementite

or "white" cast iron that usually occurs where the large mass of the iron meets the weld and chills its borders. With the use of the nickel-alloy electrode there is perfect merging from the steel alloy weld into the body of the iron casting.

Tightness in a weld will depend on the continuity of the bond between the cast iron and the first layer of deposited metal. Leaks usually occur through this zone, particularly when studs are used. Care in making the weld and the avoidance of any signs of porosity are the only means of making a tight weld. Peening will close openings through the deposited metal but will only cause trouble if attempted along the edge of the weld and against the cast iron. Sal ammoniac will sometimes seal small leaks of this nature.

CHAPTER IX

WELDING ALLOY STEELS

General Properties of Materials.—Practically all ferrous metals and alloy steels can be welded by the electric arc process with varying degrees of success. All classes of steel and iron may be satisfactorily welded with the exception of tool steel and spring steel. These two are unsatisfactory for arc welding. With the alloy steels chrome steel is difficult and molybdenum and tungsten steel are unsatisfactory.

The welding of a number of alloy steels by the arc process is still in an experimental stage, although excellent work is being done in a number of instances.

Nickel Steel.—When nickel is alloyed with steel it will be found to be of material assistance in preventing the burning out of the carbon, and nickel does not appear to be appreciably affected by the temperature of the arc, so that a very fair amount of nickel can be deposited without loss. The only disadvantage of the nickel alloy steel deposit lies in its tendency to exhibit incipient hair-line cracks on the surface. These are superficial and do not actually affect the weld, but they do mar its perfect appearance. However, it has been found that the introduction of chromium in the nickel of the alloy will prevent these surface cracks. From the foregoing it will be seen that nickel and chrome nickel alloys may be satisfactorily welded even with the bare wire electrode. Alloys of this type containing about 3½ per cent nickel and 1½ per cent chromium or similar combinations, are in universal use in automobile construction. When the welding rod can be made approximately to duplicate this analysis, the tensile strength of the finished weld may be increased greatly.

There are other chrome nickel steels which have the highly desirable properties of strength and non-corrosion, and which contain 30 to 40 per cent and over of alloy. It is practically impossible to weld metals, of this high alloy content, with a bare wire electrode, no matter how closely it resembles the base metal in analysis.

It would appear that this unfortunate deficiency is caused by the increase of chromium and other nickel alloy ingredients, because pure nickel welds satisfactorily, and any compound like nickel-iron and nickel-copper or nickel-manganese, each with or without iron, can be arc welded, but not as easily with bare as with coated electrode. A deoxidizing flux coating aids in welding these alloys of nickel in the same manner as when used for welding monel metal.

Manganese Steel.—All blow-holes and cracks to be ground out with an emery wheel before welding is started. The work is made the negative line of the welding circuit. Using a 5/32-in. or a 3/16-in. electrode, the metal is laid down in strings of beads using just sufficient current to get good fusion and not puddling the weld any more than is necessary. The material being welded on is kept as cold as possible, and where the work is done in the shop, it may be all but the upper surface submerged in circulating water. About 4 in. of bead is laid down and then immediately after the red color has left, it is sharply hammered with a hand hammer, which stretches the deposit metal and prevents checking. Immediately after hammering if water is poured over the weld and the surrounding material it will cool it and prevent the work from getting at all warm. If the metal is deposited in this manner and each short bead sharply peened a deposit of tough, wear-resisting material will be obtained, which is free from checks and hair cracks.

The pouring of water over the weld is not to be misconstrued as a quenching action. It is only to cool the work. The cold work quenches the deposit as soon as it strikes it. The hammering is very essential as it not only stretches material but also cleans it from the scale which gathers during welding and has a forging effect upon the deposit, which makes it tougher and harder than simply allowing the deposit material to cool as a casting.

Vanadium Steel.—Vanadium when present in commercial steel is fortunately found in very small amounts, and when this alloy is welded the vanadium escapes at the temperature of the arc. Nevertheless, vanadium steel electrodes give the weld a greater tensile strength—the value of the increase ranging somewhere between those of manganese and nickel chrome steels. At present, however, the use of vanadium steel welding rods is not extensive commercially.

It is a curious fact that the three alloys, vanadium, manganese and carbon can increase the strength of the weld after they have been removed from the metal, and perhaps vanadium as an alloy is the most remarkable in this connection because a weld made with a rod containing even 0.01 per cent of this alloy will produce a noticeable increase of strength in the deposited metal, although not even a trace of the element can be assayed in the finished weld.

Silicon Steel.—Silicon steel is usually found in commercial use in the form of very thin sheets, and therefore is not often met with in welding practice. However, silicon presents no difficulty to arc welding, and its presence in the melted electrode is favorable to

the process, as it is effective in collecting and floating dross and slag to the surface of the weld. This is why silicon is an active ingredient in almost every slag coating, for its settling and quieting action is most valuable. Commercial steels do not contain high percentages of silicon, but if an alloy of high silicon content were to be welded, it would probably behave like alloys of manganese or chromium.

Aluminum and Magnesium Steel.—Commercial aluminum and magnesium steel alloys of low alloy content are easily welded. Both these elements are very valuable in an electrode coating because of their fluxing action. Steels containing large percentages of aluminum and magnesium have not yet been commercially arc welded. This also applies to steels with high content of tungsten and molybdenum.

Stainless Steel.—The art of welding the new Stainless Steel Alloys is under development. At the present time it is possible not only to weld all of them that have been developed by the use of a special electrode and special welding apparatus, but also these new stainless steels can be deposited on mild steel or even on cast iron so as to form a non-corroding or heat resisting surface.

These alloys are divided into two general classes, the chromium iron class and the copper bronze class. The copper alloys weld best with a strip of the same material, using the D.C. process, while the chrome alloys weld best with alternating current, using a special rod deposit to give the analysis desired, the rod itself being ordinary mild steel or medium high chrome nickel carbon steel.

CHAPTER X

WELDING NON-FERROUS METALS

Welding Non-Ferrous Metals.—Non-ferrous metals as commercially used are more or less difficult to weld by the electric arc although some welding is actually done. The application of the electric arc process to the welding of non-ferrous metals is still in its experimental stages.

Copper.—It was found that for the arc welding of copper several compositions are suggested to be used as electrodes. One writer suggests the use of tinned copper surrounded with a flux covering. Another one states that the filler material consists of copper wire containing, apart from the quantity of phosphorous required for the welding, silver or bismuth up to 5 per cent.

It is suggested that a flux producing a powerful reducing atmosphere should be used. Borax is also advised.

The graphite arc seems to be the accepted method to be used in the welding of copper, although phosphor copper is used with reverse polarity (electrode positive).

Nearly all of the writers agree that the line of the weld should

be preheated to a dull red before welding, and the welding done as rapidly as possible, adding an excess of material.

There seems to be some disagreement among the writers as to the use of hammering. Some claim that hammering is unnecessary, others claim that it improves the welded joints. Where hammering is recommended it is suggested that the weld in thin plates should be hammered cold and then annealed, but in bars or thick stock the hammering should be done at about 500 deg. C., then annealed at 500 deg. C. and plunged in cold water.

The material to be welded should be prepared in the same manner as iron or steel and if the sections are thin graphite, asbestos mill board or fire brick should be used to back up the metal.

It has been found that sulphur, antimony, lead and copper oxide make the deposited metal brittle.

The current used is determined by the thickness of the metal to be welded and when using graphite electrodes should be as low as possible.

Some claim that the deposited metal is free from porosity while others claim that porosity can not be eliminated.

About the only practical use given in the literature for the arc welding of copper is on the welding of copper bonds on to steel rails.

Brass and Bronze—The welding rod should be very pure and contain a very small amount of aluminum, which is necessary to deoxidize the welds.

A cleaning flux is indispensable and should have the function of dissolving the alumina produced during the oxdizing process.

One of the best fluxes is made of powdered salt (NaCl), borax ($Na_2B_4O_7$) and boric acid (H_3BO_3). It is suggested that the filler rod be coated with this flux before welding.

Since the heat conductivity of brass and bronze is appreciably lower than copper, preheating is not as essential.

Brass containing 65 to 70 per cent of copper should be hammered while cold, then annealed at a temperature of 650 deg. C. (1200 deg. F.), but in no case as high as 800 deg. C. (1472 deg. F.). This operation is indispensable to satisfactory work. Bronze should not be hammered while hot as the material at high temperature is very fragile. In the case of brass containing 58 to 60 per cent of copper the weld should be hammered at a temperature of 500 deg. C. (932 deg. F.). Annealing is not necessary unless the hammer marks are to be removed.

The use of the graphite arc with a metallic filler rod is generally advised.

Bronze being more fragile than brass or copper when hot should be supported during the welding process by graphite, mill board, or fire brick.

Tin and Lead.—Tin and lead appear to possess too low a melting point for the high temperature of the welding arc, but these metals are satisfactorily welded by the contact or semi-arc process and

are easily and neatly cut or burned by the same method. The semi-arc process is also very useful in the deposition of pure nickel, manganese alloys, or monel metal for the satisfactory repair of defects in cast iron. In this process, as its name implies, the arc is intermittent and the electrode is brought into interrupted contact with the parent metal. This keeps down the heat and while the deposit is intermittent, the whole is easily worked into homogeneous mass by skillful arc manipulation.

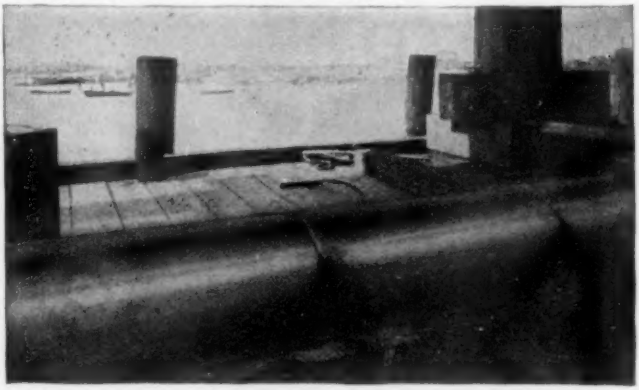


Fig. 51. Arc welding a bronze propeller sleeve

Monel Metal.—Monel metal, which is an alloy of nickel and copper, is very useful for welding. This metal is placed on the market just as it is reduced from the ore, so that the alloys it contains occur naturally. The content of this metal seems well adapted to arc welding.

CHAPTER XI

IMPORTANT REPAIR WELDING

The purpose of this discussion is to call attention to what may be called "precision welding." When the word "precision" is used the full meaning of the word should be understood as not exact but as permitting a tolerance of less than two thousands of an inch. It was not so long ago that even the machining of a large crank shaft to two thousandths of an inch tolerance was not an easy problem, especially when its assembled or complete weight was between 5 and 75 tons. Today, however, this is the standard tolerance and is lived up to by reliable engine manufacturers.

Alignment.—It is possible, through the use of precise measuring instruments, which are capable of measuring the alignment of a broken part, to repair a broken casting or forging with a considerable degree of accuracy.

One can readily understand that a piece of machinery can not

be lined up any closer than the alignment of its machined surface. Machining faults can be corrected to a considerable degree in large machined pieces even after considerable use, and when age, with its normalizing influence, has caused a warpage or springing of a crankshaft, because of the original forging strains, the shaft may be straightened to its original tolerance at small labor cost.

The classes of work coming under the head of precision jobs not only include crankshafts of steel but also cast iron or cast steel as well, and the term may be employed wherever a large mass of steel requires bending, straightening or twisting. This twisted condition can be reduced within certain limits by the electric arc.

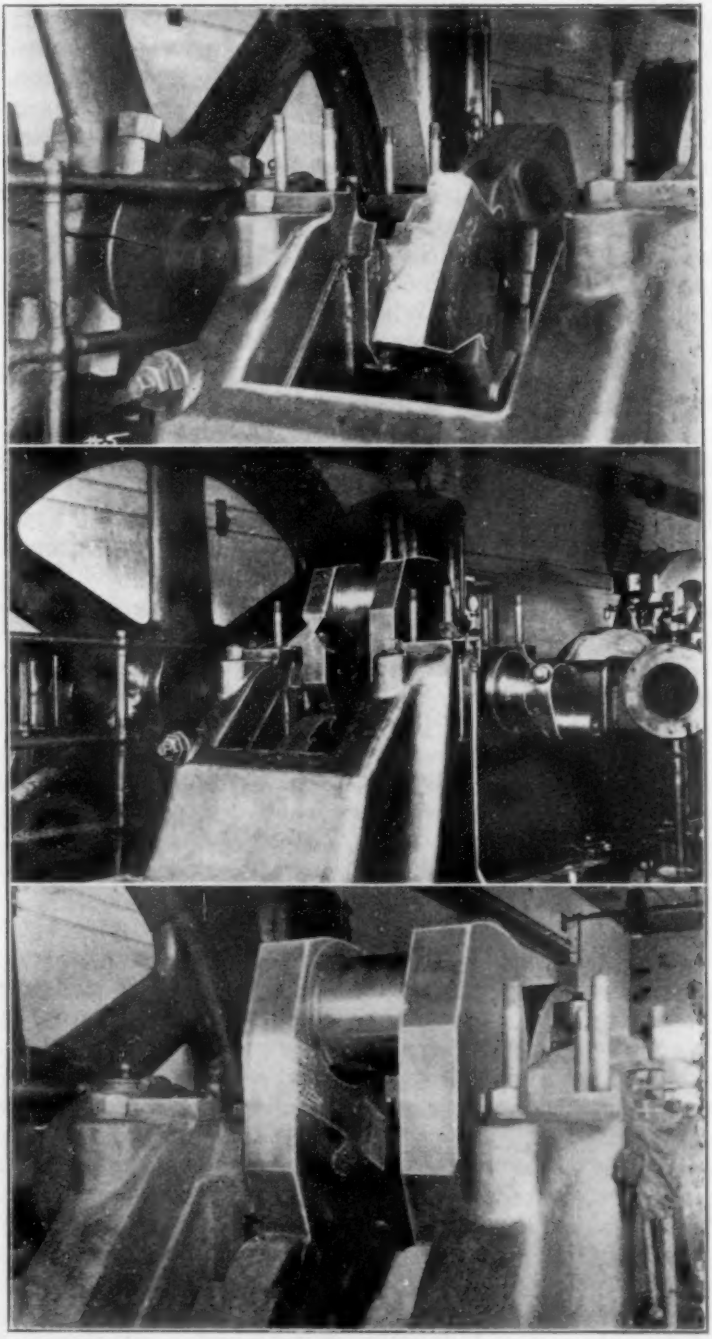
A high pressure cast iron cylinder may have its flange broken off completely around the cylinder. Although a delicate problem, it is a practicable undertaking to replace this flange on cylinders and also to have its gasket face alignment equal to the original. In undertaking work of this nature a complete practical knowledge and understanding of expansion and contraction of metals is necessary. The operator or supervisor must thoroughly understand the use of precision instruments, some of which he must be capable of devising himself to suit the individual problem confronting his work. The metal arc process is in general very satisfactory for this class of repair and when used comparatively small electrodes and medium current values are preferable.

The process and method of repairing the crank shaft is shown in Figs. 51 to 53. This shaft when completed was accurately aligned to a tolerance of 1¼ thousandths of an inch. The process in this particular weld was as follows:

The fracture was chipped off from opposite sides, as shown in Fig. No. 52. In a round section it should be chipped to a point, leaving a "vee" of approximately 90 deg. between the two pieces when they are assembled. The metal should be thoroughly clean and free from carbon pockets or shrinkage cracks before attempting to weld. The two parts were then placed together with the points of the "vee" or chipped section in line with each other and with an opening between them of ⅛ in. or more, so that complete fusion of the added metal with either side of the "Vee" might be obtained.

Tacking.—The next step to be taken was the alignment of the work which, without question, was the most difficult problem to be encountered in the whole repair procedure. Provision had to be made in the original alignment for shrinkage of the metal of the primary weld by which the two pieces were tacked together. When this alignment was completed and the connecting weld was made, check measurements were taken from the sides.

In this connection it is often found that the shrinkage of the "tacking" weld is greater or less than anticipated. Such errors can be corrected within reasonable limits by the use of a peening hammer to effect an expansion, if contraction is required, of not exceeding three or four thousandths of an inch, the application of



Figs. 52, 53 and 54. Precision welding used in repairing a crankshaft so that when completed shaft was accurately aligned to a tolerance of 1¼ thousandths of an inch. Upper figure shows break in crankshaft. Center figure shows double V joint after alignment and tack welding. Lower figure shows completed weld

one additional layer of metal may give the desired result. In no case should a contraction be allowed to remain in more than two layers of the original connecting weld. When the error in alignment exceeds three or four thousandths in either direction, good practice makes it necessary to chip out or break through this original weld and then start over again. The operator may have to repeat this operation several times before an absolute zero point is obtained. When this operation has been successfully accomplished, the most difficult part of the job is past.

Removing Contraction Stresses.—The process from then on consists solely in the repeated application of single layers of metal on both sides of the weld. When applying these additional layers, if desired, each layer may extend over the whole fractured surface. Shrinkage stresses which will be set up in each layer, may be removed by the use of a peening tool. Additional metal must not be applied at any time until all shrinkage of the metal already deposited has been relieved, so that all alignment indicators reach zero. It is advisable during the application of a layer, to occasionally watch the indicators so as to note the location and the amount of the actual stresses. By continued observation of the micrometers while welding, the operator can keep fully informed on any contraction that takes place. This same observation is advisable during the peening process so that the operator may familiarize himself with the actual amount of peening required to obtain a neutral weld. The understanding of contraction and expansion, on the part of the welder, as above outlined, will, in the course of a short time, enable him to estimate very closely the amount of peening necessary on work where the use of precision instruments is not practicable and should prove a very valuable asset to any operator.

The extent of contraction varies considerably and usually is in direct proportion to the variation in carbon of the base and weld metals. Any deflection sideways in the welding of the crankshaft may also be corrected by peening. It is essential that no more than one layer be applied over the entire surface of any precision weld before peening, since it has been definitely proved that the effect produced by the miniature forging blows of a pneumatic hammer does not extend into the metal any deeper than ¼ in.

The expansion by peening of a second layer on top of a layer that has been applied without peening, will create a tensile stress severe enough to probably cause a fracture in the underlying layer. There are also times when, due to the thickness of a layer, and also due to its hardness caused by the use of a particularly hard metal, the contracting stresses can not be relieved until continued peening has flaked off a certain amount of the surface of the weld. It is known that when a thin layer of white hot metal is evenly applied to colder metal, it sets up tremendous stresses. When added metal is applied with a thorough knowledge of these facts these stresses can be used to accomplish desired distortions in

large steel sections which can not be obtained as effectively in any other manner. It is also known that this thin layer of metal which has tied up in itself many pounds of pull created by contraction, can readily be normalized or expanded to a normal condition by means of the forging effect of a peening hammer. Layer upon layer may be applied in this way with absolute confidence that, if carefully and accurately applied, the finished mass of metal when tested with micrometers or indicators as gages will be absolutely normal or neutral with neither expansion nor contraction stresses. In this way the necessity for annealing is eliminated.

CHAPTER XII

CARBON ARC WELDING AND CUTTING

Carbon Arc Welding.—The difference between the metal arc welding process and the carbon arc welding process is quite marked and has already been partially discussed on previous pages. Historically, the carbon arc process was the first arc welding process discovered and was used during the last quarter of the 19th Century. Metal arc welding as a process was developed from the carbon process.

The manipulation of the carbon arc is similar to the manipulation of the gas torch used in gas welding. With the carbon arc process the heat of the arc is used to melt the work-piece or parts to be welded and, where metal is added to make the weld, the heat of the arc also melts the filler metal thus causing fusion to take place.

With the carbon arc process the electric current passes between a carbon rod, called the electrode, and the metal parts which are to be welded. Any metal which is added to the weld comes from a filler rod which is either fed into the arc by the operator or is laid along the weld before the welding process is started.

Carbon Arc Welding Without the Use of Filler Metal.—In some instances the carbon arc process is used to weld thin material with lap joints or edge welds. When this is done the heat of the arc simply melts the adjoining edge and surface or adjoining edges together and very rapidly in the case of the edge weld. In the lap joint, the edge of the top plate is melted down and fused with the under plate. On straight butt welds additional metal is usually required.

Carbon Arc Welding With the Use of Filler Metal.—When welding with the carbon arc, the necessary filler metal is added by inserting a rod or wire into the arc where the rod melts and is deposited in the crater or hollow place formed by the arc in the parts to be welded. The carbon arc process is manipulated similar to a gas torch and heat may be applied to any extent desired without adding any filler metal and when filler metal is needed it may

be easily supplied by inserting the tip of the filler rod in the molten pool of the arc crater. For this reason the carbon arc process is better suited for some classes of welding than the metal arc process. The welding of non-ferrous metals is an example of this statement, as is also the filling of blowholes in castings in a foundry.

For carbon arc welding a source of welding current which will deliver a maximum of from 400 to 600 amperes and a minimum of about 40 will be required. The additional equipment includes a carbon electrode holder and electrodes of various sizes. While the face shield may be used when cutting, it will be necessary to use a helmet when welding since both hands are required for this process.

The Electrode.—The holder should grip the carbon electrode from 4 to 5 in. from the end. The electrode should preferably be tapered to a blunt point at the working end so as to keep the arc from wandering over the end of the electrode. As the electrode burns away with use, the holder should be moved back along the electrode in order to keep the working length of carbon constant. The burning away of the electrode will tend to keep the taper approximately constant. Due to the greater intensity of the light emitted by the carbon arc, darker protective lenses are necessary than in metal arc welding.

"Striking" the Arc.—The carbon arc is very stable and easy to maintain. The length of the arc can be varied over wide limits without causing it to be broken. There is no tendency for the electrode to "freeze" or stick to the work piece as in the case of the metal electrode. Accordingly, the arc can be "struck" without difficulty at any point and be rapidly moved over the surface of the work to the point where the weld is to be made.

Depositing Metal.—In order to unite two masses of metal under the conditions encountered in arc welding, it is necessary that the adjoining surfaces, at least, be thoroughly fused so the metal can flow. In welding with the carbon electrode, a molten pool should be formed on the work and the added metal deposited in this pool. The arc should be kept at this point until the added metal is thoroughly melted and mixed with the original metal before more material is added. Usually the added metal is in the form of a long stick of filler rod held in the welder's left hand. When the pool or the work is ready, the end of the filler rod should be inserted in the pool and the arc directed against the rod just above the surface of the molten metal. The arc will melt through the rod and leave the end in the molten pool on the work. The arc should then be played about on the pool until the added metal is all melted down, at which time, due to the circulation caused by the heat, the molten metal will be well mixed. After this operation is completed the filler rod may be again inserted in the pool and the process repeated along the line of the weld.

Position of Electrode.—In welding or building up, the carbon electrode is generally held in a plane perpendicular to the surface

of the plate, but with the electrode inclined ahead about 15 deg. toward the line of weld so as to direct the arc back into the weld. This position is illustrated in Fig. No. 55.

Direction of Travel.—By welding from left to right, a right-handed welder avoids getting into awkward positions. In Fig. No. 55 the operator should be on the left of the work. The arc is

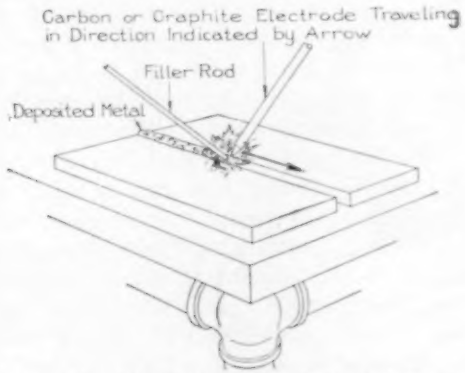


Fig. 55. Direction of travel in making a carbon weld

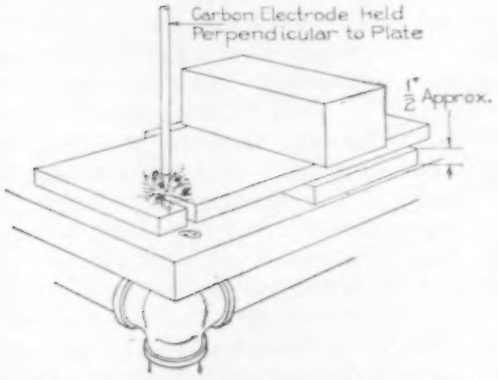


Fig. 56. Cutting a steel plate with a carbon or graphite electrode

thus directed backward into the weld and the position of the arms and hands is comfortable.

Welding.—With the work, electrode and filler rod in position, as shown in Fig. No. 55, the welder should begin to weld at the end where the plates are close together and proceed to fuse the edges of the work pieces, following a horseshoepath, as illustrated in Fig. No. 55, and working forward along the edges of the plates about 1 in. This procedure will melt down the edges of the plates and the filler metal should then be added at the back of the horseshoe.

Inspection.—When the joint has been completely welded the welder should inspect it and then break it and examine the weld.

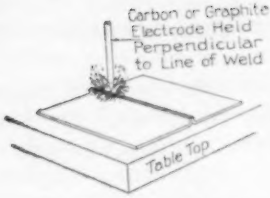


Fig. 57. A type of service weld used on thin sheet metal

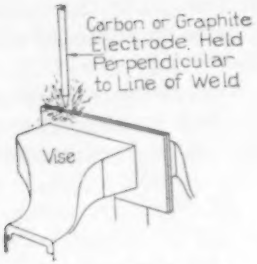


Fig. 58. Welding the edges of two thin plates with the carbon arc

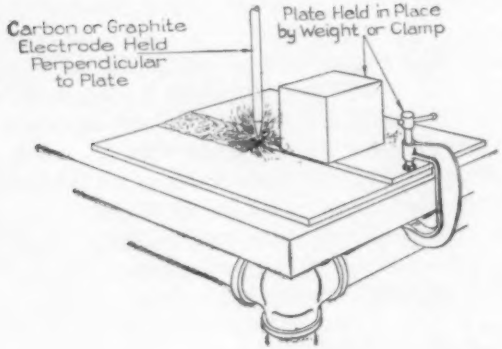


Fig. 59. Method of making fillet weld on thin sheet metal with the carbon arc

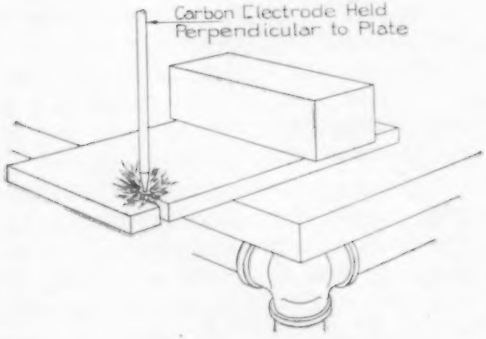


Fig. 60. Cutting a steel plate with a carbon or graphite electrode

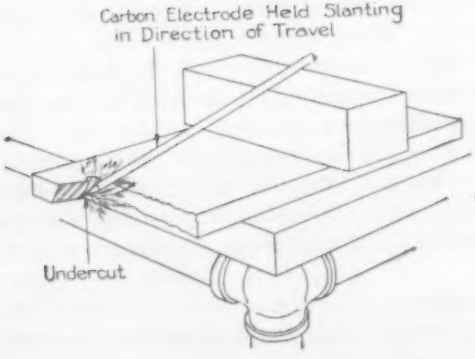


Fig. 61. Method of undercutting to allow molten metal to run out more easily

If the arc is kept on a small area for too long a time, the metal will be overheated and boil. In this condition it "froths" and will be spongy and porous when cool. The welding operation should progress fast enough so as to avoid this condition.

Edge Welds on Thin Sheet Metal.—Fig. No. 58 shows two pieces of thin sheet metal clamped in a vise for welding the edges together. The welder should "strike" the arc at one end and move it along the edge of the sheets, fusing them together and then turn the strips over and weld the other edge in the same way. The weld should then be inspected for smoothness of surface, and absence of porous spots. It should be deep enough to provide a good bond. To test the weld clamp the finished piece in the vise with the end uppermost and drive a cold chisel between the strips so as to wedge them apart and so as to tear or break the weld. The strength and general characteristics of the weld should then be noted and this information made use of in future welds.

Fig. No. 57 shows a similar weld, but with the two pieces of metal laying in a horizontal position for a butt weld.

Making a Fillet Weld.—When making a fillet weld, such as illustrated in Fig. No. 59, using a carbon arc, the operator should strike the arc at one end and slowly move it along the line of the weld. The heat of the arc should fuse the edge of the upper strip and extend or penetrate into the lower. The degree to which this fusion takes place depends on both the current and rate of travel of the electrode along the weld. Penetration can be increased by reducing the rate of travel until a point is reached where the heat spreads out on the upper strip and causes the fusion of too wide an area. When this condition is found to exist the operator should increase the current and increase the rate of travel of the electrode. Experience will show the best combination to use.

After completing the weld the operator should inspect the back of the lower plate. This inspection should show that the metal was almost fused through. Whether it has almost fused through or not will be indicated by small, flattened drops just forming and the heated appearance along the weld. To test the strength of the weld he should grip one strip in the vise and tear the other one free by pliers or by a hammer and chisel. In this test the weld should not break but the metal should tear in the strip beside the weld if it is to be regarded as a satisfactory weld.

CARBON ARC CUTTING

When the oxy-acetylene torch is used for cutting ferrous metals the metal is first heated to the fusion or melting point and then a stream of pure oxygen gas used to literally burn or oxidize a path through the metal which, in the presence or pure oxygen, burns very rapidly.

Unlike the above process, carbon arc cutting depends upon the

melting process alone, except where a combination of the carbon arc with oxygen gas is used for certain work. When using the carbon arc for cutting space must be left under the plate for the molten metal and slag to run out of the cut. This space is provided in the illustration shown in Fig. 60 by inserting a ½-in. block under the plate to be cut. The operator should "strike" the arc at the edge of the plate and hold it still until the metal melts and drops away and then move the arc along the line of the cut as rapidly as the metal melts and drops away.

"Burning" Holes.—Whenever the carbon arc is to be used for "burning" holes in metal the operator should hold the electrode in a stationary position while directing the arc at the point where the hole is to be made. When the heat first penetrates through the plate and the molten metal begins to run off, the electrode should be removed. As the metal cools somewhat he should repeat the operation and enlarge the hole to the desired size.

When the hole has been made the desired size he should inspect it for smoothness of the edges and for the required dimensions to which it was to be made. He should also check it for location particularly after any enlargement to see that the removal of this additional metal has been uniform all around the edge. If this checking is not done properly the center of the enlarged hole will be different from the original center.

CHAPTER XIII

QUALIFICATIONS FOR ARC WELDERS

Selecting Applicants for Training.—The unique nature of welding work makes necessary the selection of applicants for training with regard not only to their mechanical fitness for the work, but also with regard to their ability. The character of the work permits of opportunities for unreliable or dishonest workmen to conceal poor or unsound welds, which may endanger human life and property, and prevent a natural development of welding in industrial establishments.

A consideration of the qualifications requisite to success as a welder indicates that some definite procedure can be set up by which it will be possible to give a degree of assurance that a prospective applicant for training either does or does not possess the necessary qualifications.

Failures of greater or lesser importance have occurred. These failures may have been caused by improper design, improper welding methods, lack of knowledge or failure to realize responsibility, not only on the part of the welder, but on the part of those employing him. It therefore seems necessary for those employing or training welders to see that the applicant has the necessary funda-

mental qualifications to insure his doing good work after proper instruction. These qualifications are as follows:

a. The presence of a job conscience and of a job pride.
b. The possession of necessary physical qualifications.
c. A sense of responsibility for "safety first."
d. Ingenuity and resourcefulness.

Job Conscience and Job Pride.—The presence or absence of a job conscience or job pride can be determined to a certain extent from the knowledge of the occupation previously followed by the applicant. While a successful experience in any occupation may not indicate that the applicant will become a good welder after receiving proper training, yet, on the other hand, the fact that he has successfully worked for satisfactory periods of time in certain kinds of occupations, may be taken as a point in his favor which indicates that he will make a good welder in so far as it is necessary for him to be a man who takes pride in his work and who is conscientious.

As an illustration of the above statement, certain occupations are submitted as examples which by their very nature tend to develop on the part of the man the feeling of responsibility. While the occupations given below may not be those from which men aspire to become welders, yet they may be used to illustrate the point in question.

Certain types of occupations are of such a nature that inspection will not show whether the job has or has not been properly done and therefore the responsibility for successful work rests entirely upon the workman. Where a man can show successful experience through a satisfactory period of years in any one of these occupations, we are justified in assuming that he possesses that sense of responsibility known as a job conscience or a job pride.

As illustrations of this group, we have the train dispatcher, mail clerk, boiler inspector, elevator inspector, building and insurance inspectors, many railway jobs or occupations, employees in power plants, in chemical plants where occupational dangers exist, as well as any occupation which has been followed by craftsmen, the term commonly used to distinguish a skilled worker from the ordinary quantity production worker.

Certain occupations which have grown up as the result of quantity production, by the very nature of the employment leave little responsibility upon the individual workman, since automatic machines and devices determine the quality and often the quantity of the output. Here also little responsibility is present on the part of the worker for ultimate inspection, the inspector being responsible for the quality and accuracy of the output. This group of occupations due to the lack of immediate responsibility placed upon the worker tends to develop very little his sense of responsibility and job pride. Attention is called to the fact that employment in occupations of this type does not of itself necessarily prevent the individual from becoming a good welder, but on the other hand, ex-

perience in such jobs is no indication of his having developed the sense of responsibility and job pride which is desirable as a prerequisite to his being trained as a welder.

Experience in training welders does not indicate that mechanical skill in any of the so-called skilled trades is necessary as a qualification for a welder. However, where an individual possesses the other necessary qualifications, experience in these trades is an asset that would assist him in many of the jobs which he is called upon to do as a welder.

In addition to the consideration of the character of the occupation previously followed, attention should also be given to the average length of employment during which the worker held previous jobs and his reasons for changing.

Physical Qualifications.—Since welding requires the worker to use his hands and to depend to a certain extent upon his feet in handling all sorts of castings and parts, it is evident that his physical qualifications will enter more or less into the problem of selection. The following qualifications are therefore presented with a statement as to the degree to which they should be considered.

a. *Weight.*—The weight makes no difference in the man's ability to do good welding except that a heavy man, particularly if his weight is not due to mere size, is not so able to get into the awkward positions frequently required in welding work. On the other hand, some classes of work require the lifting of heavy parts in which situation a heavy man would have the advantage. In large shops it has been found desirable to arrange for helpers or chippers to prepare the work for welding rather than to call upon the welder so as to avoid fatigue of the welder's arm muscles. Welding shops should be equipped with modern handling equipment.

b. *Strength.*—For all-around job work or for handling heavy parts, physical strength is evidently an asset, but there are many welding jobs of a light character in which physical strength is not necessary and which, as a matter of fact, frequently is a liability because of the lightness and delicacy required in such jobs.

c. *Slow or Active.* Great speed of movement does not necessarily mean rapid or good work. A slow man might make every move count and an active one might waste energy by unnecessary motions, so that the question of whether a man is slow or active should be considered in the light of the meaning applied to the words. It is always true that the man who appears slow and who wastes no time, is better in welding work than the man who "fusses and sputters."

d. *Height.*—This has no effect on the ability of a man to do any welding job unless in special cases.

e. *Age.*—As a matter of general principle the younger man is easier to train than the older one, but this is frequently not true in individual cases, and the older man is more liable to appreciate and understand instructions and to realize the necessity of thought and

study in connection with a subject of which he knows very little or nothing. The question of how old a man may be is of less importance than whether or not he is still *mentally and physically flexible* so that he can adjust himself to the requirements imposed upon the welder.

f. *Dexterity.*—Arc welding is not as simple as it looks and this qualification is necessary in order that the welder may attain facility in his work. The ability to handle the welding tools with perfect freedom will prevent to a great degree the fatigue accompanying long welding jobs, thus improving the quantity and quality of the work done. A dexterous man will often be able to work in difficult places, such as overhead welding, where others fail.

g. *Eyesight.*—This is possibly the most important physical requirement. Both eyes are necessary. If a man can not see clearly what he is doing, he has no business trying to become a welder. Certain eye defects may be corrected through the use of glasses, but unless the eyesight can be made practically normal in this way the man should not be trained for a welder.

h. *Hearing.*—A successful welder should have good hearing. The lack of ability to hear is of greater consequence than the mere ability to receive directions and orders and converse with his fellow beings. There are many noises in the welding shop which defective hearing on the part of the welder would make it impossible for him to recognize conditions affecting his work and his safety.

i. *Nationality.*—The influence of nationality upon the qualifications of a welder is more noticeable where the racial habits in that particular nationality are affected by the manner in which they have been accustomed to earn a living. For example, an individual from one of the nations where much industrial development has taken place is more liable to make a good welder than one who comes from a strictly farming, fruit growing, hunting or other non-mechanical people. It should be noted, however, that the farmer boy from an advanced agricultural district, where much mechanical equipment is used, usually makes a good welder.

j. *Health.*—A man to "carry on" successfully as a welder must possess good health. Occupational surroundings are of such a nature as to make this requirement necessary.

k. *Handicaps.*—An all-around welder will require the use of both hands and both feet. Certain specialized work, however, may be done by a man who is handicapped by the loss of a leg or an arm.

Mental Qualifications.—It is evident that the successful welder should possess certain mental qualifications. Some of these, such as special skill and special knowledge will be supplied during the training period, but for the most part it is expected that the applicant for training will be already mentally qualified. In general, he should possess the following:

a. *Education.*—A man should be able to read, write and speak the English language to an extent equivalent to that covered by a common school education. It is recognized that during the recent

war, a number of men who did not possess these qualifications were trained as welders and in some cases they are still employed and making good. These conditions, however, are not the most desirable and as a general rule a man should possess the above qualifications. An elementary knowledge of arithmetic is essential. An all-around welder is called upon at different times to make measurements with precision instruments and to read elementary blueprints, which will require on his part the ability to handle numbers through common fractions and decimal fractions.

b. *General Intelligence.*—General intelligence gained through contact with business, through the reading of newspapers, through individual study, through experience in different kinds of work, and through a knowledge of building and construction material, is of great importance to the welder. A man having a broad general intelligence will be able to adapt himself to the many conditions under which he is required to carry on his work.

c. *Mental Quickness.*—The ability to observe and react in an emergency or unexpected situation is a necessary qualification for a welder.

d. *Reliability and Carefulness.*—The degree to which a man is reliable and exercises care in the performance of his work will measure his success as a welder. It is necessary that his work be always dependable, and that every care be taken not only to prevent injury to the work, to himself, and others, but also to see that the work is done so that there is no future comeback because of failure.

e. *Personal Habits.*—Personal habits affect the welder as they affect other skilled workmen. They should be considered in the selecting of candidates to the same degree they are considered in the selection of other skilled workmen.

f. *Adaptability.*—A man must be able to adapt himself to all sorts of welding conditions. He will often be required to work in undesirable places and with parts that are unpleasant to handle. The disposition and ability to fit into these situations are of great importance to success in welding.

g. *Alertness.*—The fact that there are many varying conditions to be observed during the welding of such jobs as heavy steel plate would indicate that the welder should be alert, not only to see, but to observe these conditions and act accordingly.

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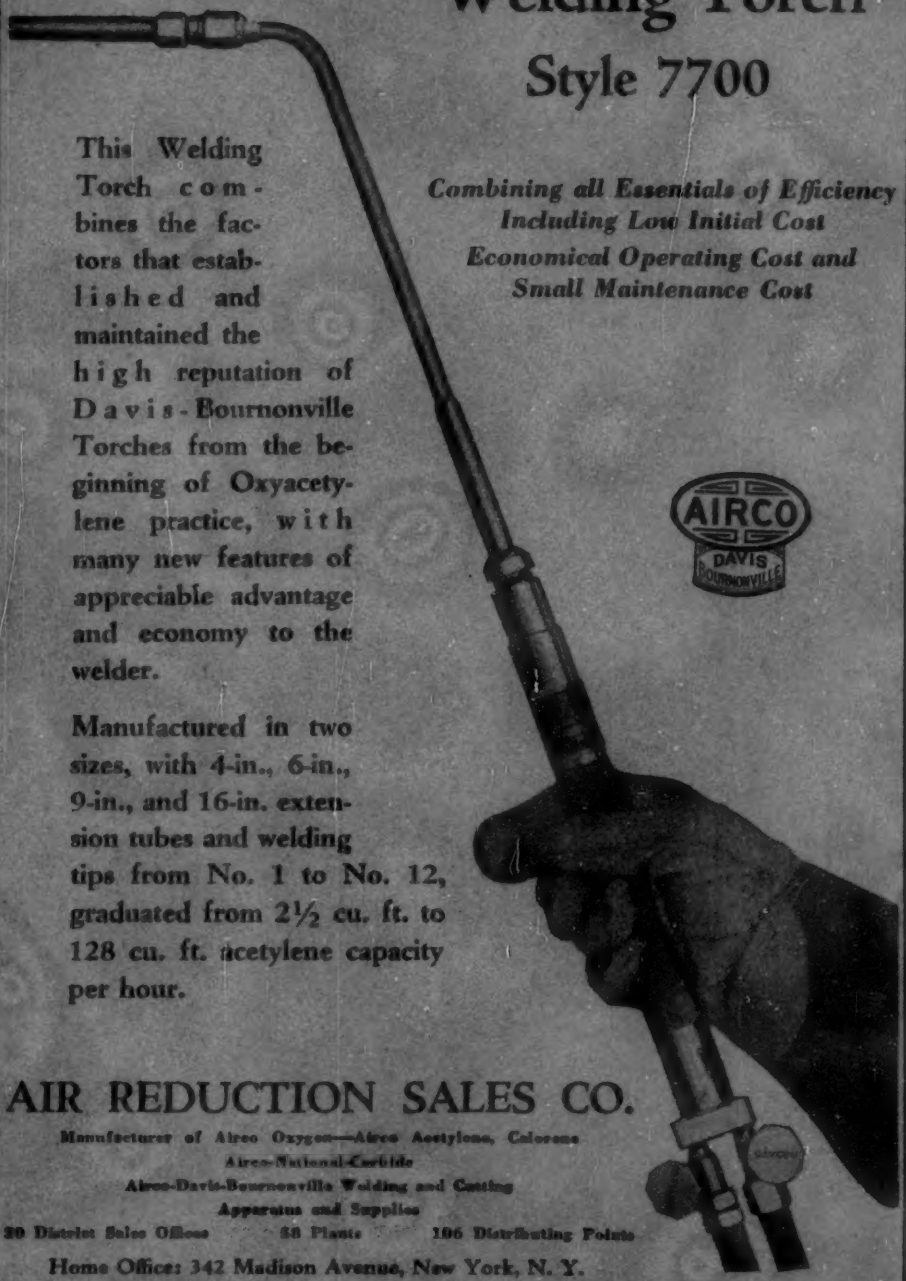

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